Implementation of Ground Source Heat Pumps in DON Facilities – A Feasibility Study

John W. Carson III

A REPORT PRESENTED TO THE GRADUATE COMMITTEE OF THE DEPARTMENT OF CIVIL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING

UNIVERSTIY OF FLORIDA

Summer 2000

AD NUMBER

DATE
15 JUNE 2000

DTIC ACCESSION NOTICE

1. REPORT IDENTIFYING INFORMATION

A. ORIGINATING AGENCY
Naval Postgraduate School, Monterey, CA 93943

B. REPORT TITLE AND/OR NUMBER
Implementation Of Ground Source Heat Pumps In DON Facilities--A Feasibility Study

C. MONITOR REPORT NUMBER
By: John W. Carson III, Thesis, U of Florida Summer 2000

D. PREPARED UNDER CONTRACT NUMBER
N62271-97-G-0052

2. DISTRIBUTION STATEMENT

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

REQUEST

1. Put your m
on reverse
2. Complete ite
3. Attach form
mailed to D
4. Use unclass
information
5. Do not order
for 6 to 8 w

DTIC:

1. Assign AD N
2. Return to re

20000710 056

DTIC Form 50
JUL 96

PREVIOUS EDITIONS ARE OBSOLETE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The Civil Engineer Corps and the Naval Facilities Engineering Command has the distinct honor and challenge to oversee all facilities management functions from design and contract, to construction, to maintenance and repair and finally to demolition and disposal. In order to assist this monumental undertaking, the Naval Facilities Engineering Command (NAVFAC) is organized with Engineering Field Divisions (EFD) and Engineering Field Activities (EFA) serving distinct geographic regions of responsibility. As Navy shore facilities continue to age, with average building ages on some stations exceeding 40 to 50 years, maintenance and upkeep costs continue to amass in the midst of military "right sizing" and budget reallocations.

As downsizing or "right sizing" continues, the DON will continue to seek a fair balance between operational/war fighting priorities and facilities maintenance and construction initiatives. Money will likely continue to follow ongoing trends and move from facilities Operation and Maintenance (O&M) budgets to the war fighting initiatives such as ships, weapons, aircraft, and research and development of new "Over the Horizon" weapons to further augment our "From the Sea" war fighting strategy. This will continue to place increased pressure of limited O&M budgets upon facilities managers that are responsible for the maintenance and upkeep of all shore support facilities. The ability to do more with less and to stretch the ever shrinking facilities O&M budgets will be key to the success of the Civil Engineer Corps in the years ahead.

Geothermal technologies have been utilized in the recent years at eleven Navy and Marine Corp installations. The success of these geothermal system implementations

merits further detailed review of the system technology and its benefits. This paper will explore the utilization of Ground Source Heat Pumps in military family housing and berthing facilities within the Department of the Navy (DON) and project potential DON wide benefits created by geothermal system implementation.

INTRODUCTION

History of Ground Source Heat Pumps

Ground-source heat pumps are not a new idea. Patents on the technology date back to 1912, in Switzerland (Calm 1987). One of the oldest ground source heat pump systems is in the United Illuminating headquarters building in New Haven, Connecticut, which has been operating since the 1930s (Pratsch 1990).[1] Although ground source heat pump systems are probably better established today in rural residential areas, the market has expanded to urban and commercial applications.

The vast majority of ground-source heat pump installations utilize unitary equipment consisting of multiple water-source heat pumps. Most individual units range from 1 to 10 tons (3.5 to 35.2 kW), but some equipment is available in sizes up to 15 tons (52.8 kW). The heat pumps are typically connected to a common ground-coupled loop. Large-tonnage commercial systems are achieved by using several unitary water-source heat pumps, each heat pump responsible for an individual control zone. One of the largest ground source heat pump systems operating today is at Stockton State College, Pomona, New Jersey, where 63 ground source heat pumps totaling 1,655 tons are connected to a ground-coupled loop consisting of 400 wells, each 425 feet deep (Gahran September 1993).[1]

In 1990, an estimated 100,000 ground-source heat pumps were operating in residential and commercial applications. In 1985, it was estimated that only around 14,000 ground-

source heat pump systems were installed in the United States. Annual sales of 17,300 units were reported in 1993 to the Air Conditioning and Refrigeration Institute (ARI), although not all manufacturers report sales figures to ARI. A Geothermal Heat Pump Consortium study dated March 1998 reported the number of Geothermal Heat Pumps installed in 1997 totaled 30,652.[8]

CHAPTER 1

Ground Source Heat Pumps – The System

1.1 How Ground Source Heat Pump System Works

Ground Source Heat Pump (GeoExchange) Systems provide space conditioning; heating, cooling, and humidity control. They may also provide water heating -- either to supplement or replace conventional water heaters. Ground Source Heat Pump Systems work by moving heat, rather than by converting chemical energy to heat like in a furnace.[1, 6, 17] Every GeoExchange System has three major subsystems or parts: a geothermal heat pump to move heat between the building and the fluid in the earth connection, an earth connection for transferring heat between its fluid and the earth, and a distribution subsystem for delivering heating or cooling to the building. Each system may also have a desuperheater to supplement the building's water heater or a full-demand water heater to meet all of the building's hot water needs. In heating mode, heat is extracted from the fluid in the earth connection by the geothermal heat pump and distributed to the home or building through a system of air ducts. Cooler air from the building is returned to the geothermal heat pump, where it cools the fluid flowing to the earth connection. The fluid is then re-warmed as it flows through the earth connection. In the cooling mode the process is reversed. The relatively cool fluid from the earth connection absorbs heat from the building and transfers it to the ground.[14, 15, 17, 18]

1.2 Ground-Coupled System Types

The ground-coupling systems used in ground-source heat pumps fall under three main categories: closed- loop, open-loop and direct-expansion. The type of ground coupling employed will affect heat pump system performance (heat pump energy consumption), auxiliary pumping energy requirements, and installation costs. Choice of the most appropriate type of ground coupling for a site is usually a function of specific geography, available land area, and life cycle cost economics.[1]

1.21 Closed-Loop Systems

Closed-loop systems consist of an underground network of sealed, high-strength plastic pipe acting as a heat exchanger. The loop is filled with a heat transfer fluid, typically water or a water-antifreeze solution, although other heat transfer fluids may be used. When cooling, requirements cause the closed-loop liquid temperature to rise, heat is transferred to the cooler earth. Conversely, when heating requirements cause the closed-loop fluid to drop, heat is absorbed from the warmer earth. Closed-loop systems utilize pumps to circulate the heat transfer fluid between the heat pump and the ground loop. Because the loops are closed and sealed, the heat pump heat exchanger is not subject to mineral build-up and there is no direct interaction or mixing with ground water.[1, 6, 14]

There are several varieties of closed-loop configurations including horizontal, spiral, vertical, and submerged loops.

1.22 Horizontal Loops

Horizontal loops are often considered when adequate land surface is available. The pipes are placed in trenches, typically at a depth of 4 to 10 feet. Depending on the specific design, anywhere from one to six pipes may be installed in each trench. Although requiring more linear feet of pipe, multiple pipe configurations conserve land space, require less trenching and therefore frequently cost less to install than single pipe configurations. Trench lengths can range from 100 to 400 feet per system cooling ton depending on soil conditions and the number of pipes in the trench. Trenches are usually spaced from 6 to 12 feet apart. These systems are common in residential applications but are not frequently applied to large-tonnage commercial applications because of the significant land area required for adequate heat transfer. The horizontal-loop systems can be buried beneath lawns, landscaping, and parking lots. Horizontal systems tend to be more popular where there is ample land area with a high water table.[1, 14]

1.23 Spiral Loops

A variation on the multiple pipe horizontal-loop configuration is the spiral loop, commonly referred to as the "slinky". The spiral loop consists of pipe unrolled in circular loops in trenches. Another variation of the spiral-loop system involves placing the loops upright in narrow vertical trenches (See Figure 1(a)). The spiral loop configuration generally requires more piping, typically 500 to 1,000 feet per system cooling ton, but less total trenching than the multiple horizontal-loop systems.[1] For the horizontal spiral-loop layout, trenches are generally 3 to 6 feet wide with multiple trenches typically spaced about 12 feet apart. For the vertical spiral-loop layout, trenches

are generally 6 inches wide and the pipe loops stand vertically in the narrow trenches. In cases where trenching is a large component of the overall installation costs, spiral-loop systems are a means of reducing the installation cost. As noted with horizontal systems, slinky systems are also generally associated with lower-tonnage systems where land area requirements are not a limiting factor.

1.24 Vertical Loops

Vertical loops are generally considered when land surface is limited. Wells are bored at typical depths from 75 to 300 feet deep. The closed-loop pipes are inserted into the vertical well. Typical piping requirements range from 200 to 600 feet per system cooling ton depending on soil and temperature conditions. Multiple wells are typically required, typically spaced between 10 and 16 feet apart and piped either in series and/or in parallel in order to achieve the total heat transfer requirements[1] (See Figure 1(b)). Vertical systems tend to be more popular where land area is limited, where the water table is deep, and where the ground is rocky or bedrock. There are three basic types of vertical-system heat exchangers: U-tube, divided-tube and concentric-tube (pipe-in-pipe) system configurations. Vertical loop systems require less total pipe length than most closed-loop designs and less surface ground area. This system also requires drilling equipment with costs that exceed horizontal trenching costs.

1.25 Submerged Loops

If a moderately sized pond or lake is available, the closed-loop piping system can be submerged (See Figure 1(d)). Some companies have installed ponds on facility grounds to act as ground-coupled systems, as well as, to improve facility aesthetics. Submerged-loop applications require some special considerations, and it is best to discuss these directly with an engineer experienced in the design applications. This type of system requires adequate surface area and depth in order to function adequately in response to heating or cooling requirements under local weather conditions. In general, the submerged piping system is installed in loops attached to concrete anchors. Typical installations require around 300 feet of heat transfer piping per system cooling ton and around 3,000 square feet of pond surface area per ton with a recommended minimum one-half acre total surface area.[1] The concrete anchors act to secure the piping, restricting movement, but also hold the piping 9 to 18 inches above the pond floor, allowing for good convective flow of water around the heat transfer surface area. It is also recommended that the heat-transfer loops be at least 6 to 8 feet below the pond surface, preferably deeper.[1] This maintains adequate thermal mass even in times of extended drought or other low-water conditions. Rivers are typically not used because they are subject to drought and flooding, both of which may damage the system.

1.26 Open-Loop Systems

Open-loop systems utilize local ground water as a direct heat transfer medium instead of the heat transfer fluid described for the closed-loop systems. These systems are sometimes referred to specifically as "ground-water-source heat pumps" to distinguish

them from other ground source heat pumps. Open-loop systems consist primarily of extraction wells, extraction and re-injection wells, or surface water systems (See Figure 1(c)).

A variation on the extraction well system is the standing column well. This system re-injects the majority of the return water back into the source well, minimizing the need for a re-injection well and minimizes the amount of surface discharge water.[1]

There are several special factors to consider in open-loop systems. One major factor is water quality. In open-loop systems, the primary heat exchanger between the refrigerant and the ground water is subject to fouling, corrosion and blockage. A second major factor is the adequacy of available water. The required flow rate through the primary heat exchanger between the refrigerant and the ground water is typically between 1.5 and 3.0 gallons per minute per system cooling ton. This can add up to a significant amount of water and can be affected by local water resource regulations. A third major factor is what to do with the discharge stream. The ground water must either be re-injected into the ground by separate wells or discharged to a surface system such as a river or lake. Local codes and regulations may affect the feasibility of open-loop systems.[1, 14]

Depending on the well configuration, open-loop systems can have the highest pumping load requirements of any of the ground-coupled configurations. In ideal conditions, however, an open-loop application can be the most economical type of ground-coupling system.

Advantages: Simple design; lower drilling requirements than closed-loop designs; subject to better thermodynamic performance than closed-loop systems because well(s) are used to deliver ground water at ground temperature rather than as a heat exchanger delivering heat transfer fluid at temperatures other than ground temperature; typically lowest cost; can be combined with potable water supply well; low operating cost if water already pumped for other purposes, such as irrigation.[1, 14]

Disadvantages: Subject to various local, state and Federal clean water and surface water codes and regulations; large water flow requirements; water avail- ability may be limited or not always available; heat pump heat exchanger subject to suspended matter, corrosive agents, scaling, and bacterial contents; typically subject to highest pumping power requirements; pumping energy may be excessive if the pump is oversized or poorly controlled; may require well permits or be restricted for extraction; water disposal can limit or preclude some installations; high cost if re-injection well required.[1, 14]

1.27 Direct-Expansion Systems

Each of the ground-coupling systems described above utilizes an intermediate heat transfer fluid to transfer heat between the earth and the refrigerant. Use of an intermediate heat transfer fluid necessitates a higher compression ratio in the heat pump in order to achieve sufficient temperature differences in the heat transfer chain (refrigerant to fluid to earth). Each also requires a pump to circulate water between the heat pump and the ground-couple. Direct-expansion systems remove the need for an intermediate heat transfer fluid, the fluid-refrigerant heat exchanger, and the circulation pump. Copper coils

are installed underground for a direct exchange of heat between refrigerant and earth. The result is improved heat transfer characteristics and thermodynamic performance.[1]

The coils can be buried either in deep vertical trenches or wide horizontal excavations. Vertical trenches typically require from 100 to 150 square feet of land surface area per system cooling ton and are typically 9 to 12 feet deep. Horizontal installations typically require from 450 to 550 square feet of land area per system cooling ton and are typically 5 to 10 feet deep. Vertical trenching is typically not recommended in sandy, clay or dry soils.

Because the ground coil is metal, it is subject to corrosion (the pH level of the soil should be between 5.5 and 10, although this is normally not a problem). If the ground is subject to stray electric currents and/or galvanic action, a cathodic protection system may be required. Because the ground is subject to larger temperature extremes from the direct-expansion system, there are additional design considerations. In winter heating operation, the lower ground coil temperature may cause the ground moisture to freeze. Expansion of the ice buildup may cause the ground to buckle. Also, because of the freezing potential, the ground coil should not be located near water lines. In the summer cooling operation, the higher coil temperatures may drive moisture from the soil. Low moisture content will change soil heat transfer characteristics.

Only one U.S. manufacturer currently offers direct-expansion ground-source heat pump systems. Systems are available from 24,000 Btu/h to 60,000 Btu/h (heating/ cooling

capacity). Larger commercial applications require multiple units with individual ground coils.[1]

Advantages: Higher system efficiency; no circulation pump required.

Disadvantages: Large trenching requirements for effective heat transfer area; ground around the coil is subject to freezing (may cause surface ground to buckle and can freeze nearby water pipes); copper coil should not be buried near large trees where root system may damage the coil; compressor oil return can be complicated, particularly for vertical heat exchanger coils or when used for both heating and cooling; leaks can be catastrophic; higher skilled installation required; installation costs are typically higher; this system type requires more refrigerant than most other systems.[1, 14]

GROUND-COUPLED SYSTEM TYPES

Figure 1

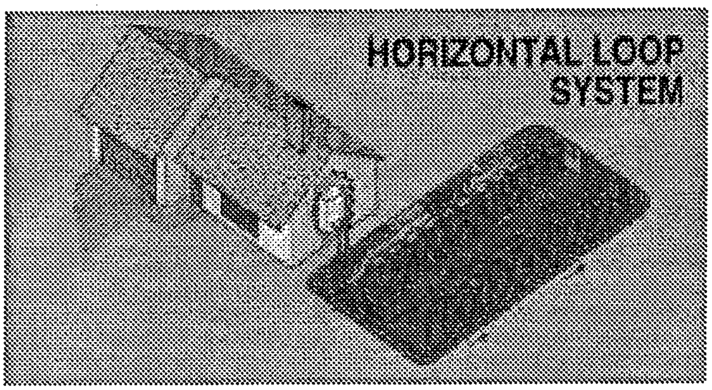


Figure 1(a)

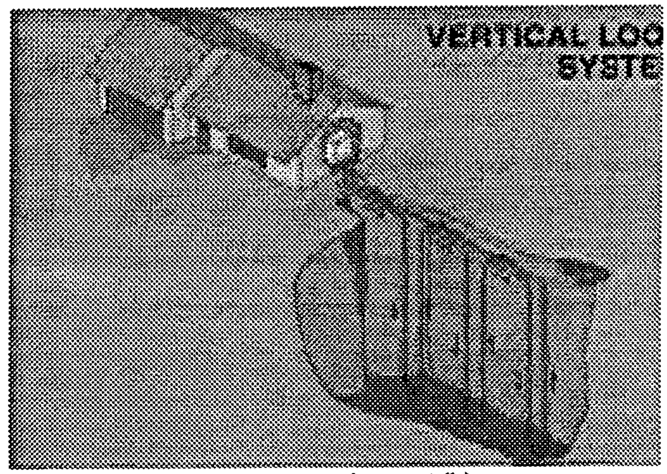


Figure 1(b)

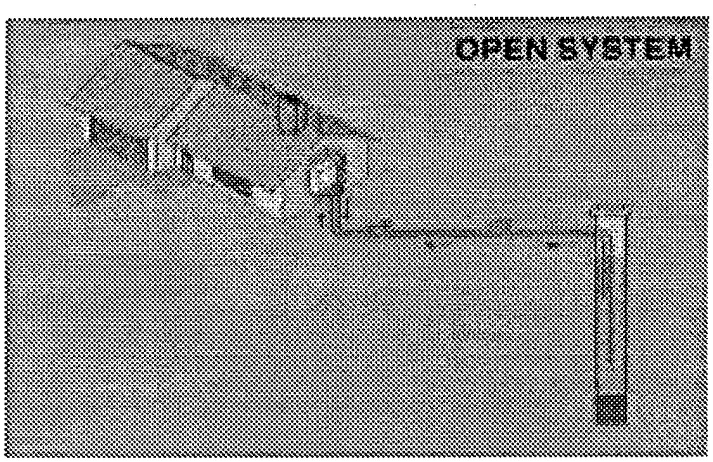


Figure 1©

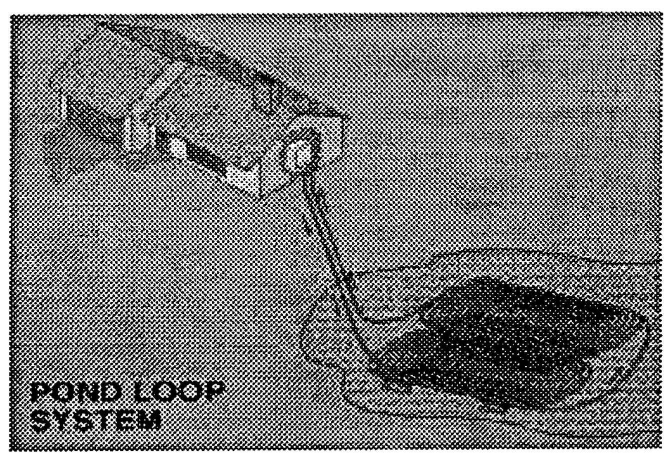


Figure 1(d)

1.3 Ground Source Heat Pump System Benefits

Geothermal/ground source heat pumps offer consumers a heating, cooling, and hot water system that is cost-saving, reliable, efficient, and environmentally sound. The unique flexibility of ground source heat pumps allows them to be used for residential and commercial buildings all across the United States, Canada, and Europe. Ground Source heat pump systems can be installed in new buildings and as retrofits in older buildings. Ground source heat pump systems have the potential to reduce consumption of cooling energy by 30% to 50% and to reduce heating energy by 20% to 40% compared with typical air-source heat pumps.[1, 3, 5]

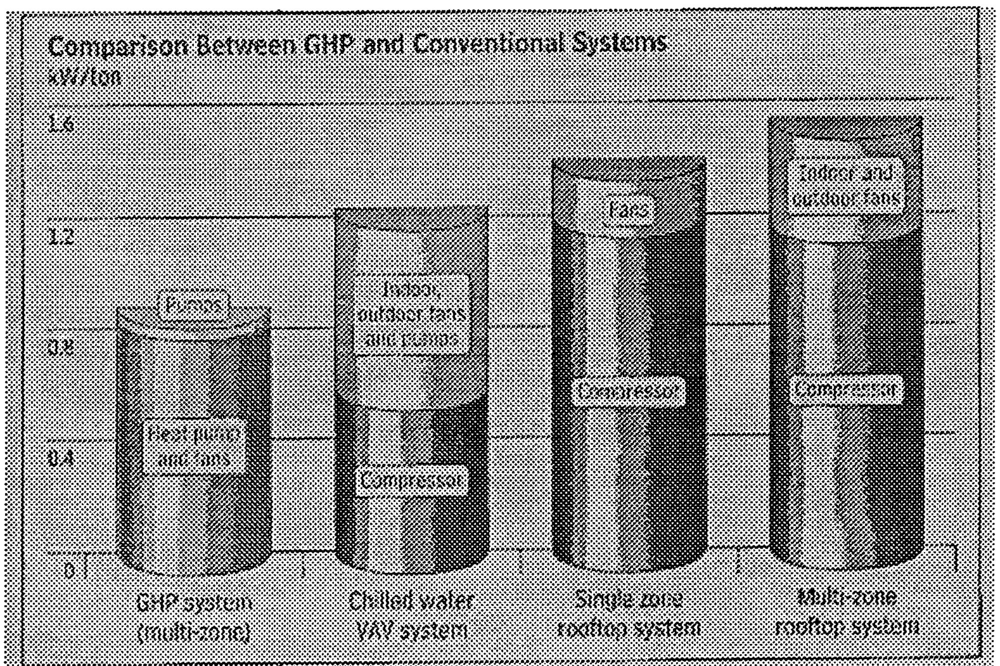


Figure 2

The primary benefit of ground-source heat pumps is the increase in operating efficiency, which translates to reduced heating and cooling costs, but there are additional advantages.

One notable benefit is that ground source heat pumps, although electrically driven, are classified as a renewable-energy technology. The justification for this classification is that the ground acts as an effective collector of solar energy. The renewable energy classification can affect Federal goals and potential funding.

Ground Source Heat Pumps use the Earth's energy storage capability to heat and cool buildings, and to provide hot water. The earth is a huge energy storage device that absorbs 47% of the sun's energy -- more than 500 times more energy than mankind needs every year in the form of clean, renewable energy. Ground Source Heat Pumps take this heat during the heating season at an efficiency approaching or exceeding 400%, and return it during the cooling season.[22] Ground source heat pumps typically use 25% less refrigerant than split system air-source heat pumps or air conditioning systems and generally do not require tampering with the refrigerant during installation. Systems are generally sealed at the factory, reducing the potential for leaking refrigerant in the field during assembly.[5] Geothermal/ground source heat pumps work with the environment to provide clean, efficient, and energy saving heating and cooling year round. Ground Source heat pumps use less energy than alternative heating and cooling systems, helping to conserve our natural resources. Ground source heat pumps are housed entirely within the building and underground. They are quiet, pollution free and do not detract from the surrounding landscape and work toward the preservation of the environment by minimizing present environmental problems like acid rain, air pollution and the destruction of the ozone layer (See Figure 3).

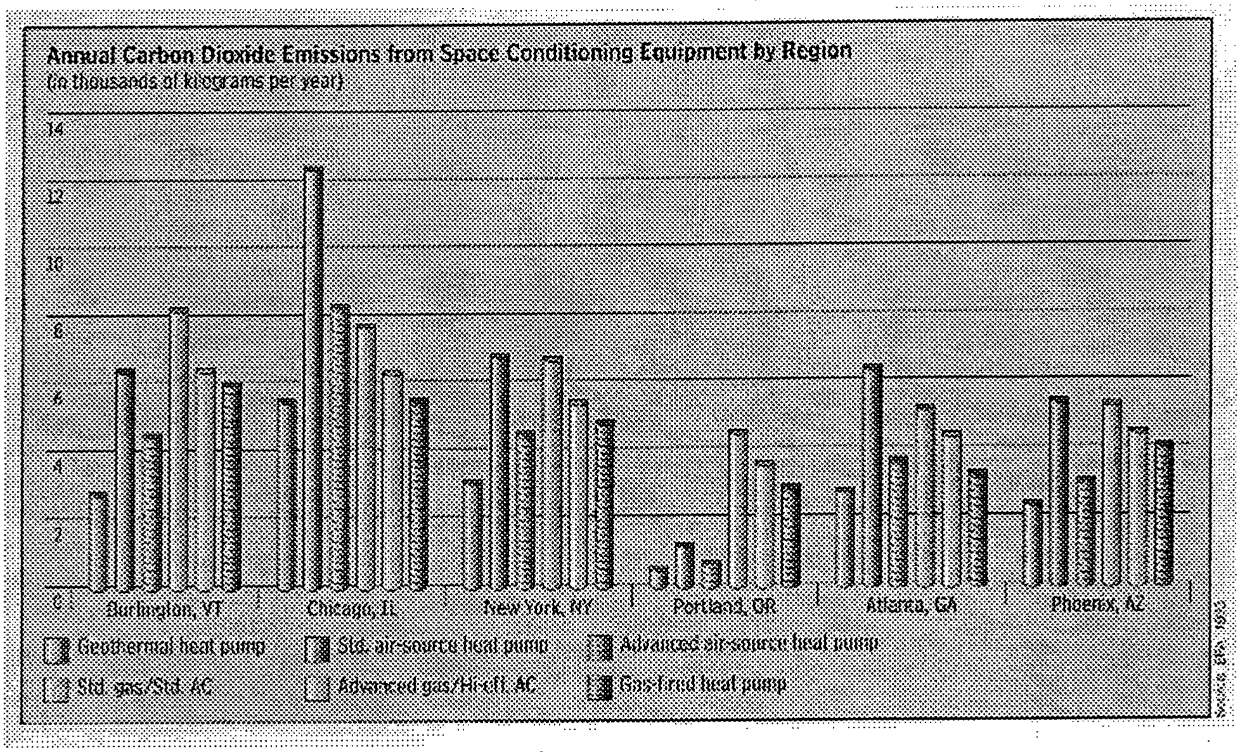


Figure 3

Ground Source Heat Pump systems can utilize heat pump technology to heat water. Water heating can be provided much more efficiently with vapor compression technology than with electric resistance or fossil-fuel fired water heating. Coupling geothermal heat pumps, either directly or indirectly, with vapor compression water heating (Desuperheaters) offers very attractive water heating costs and benefits. Desuperheaters are easily adapted to a variety of situations and they are highly efficient. Desuperheaters are comparatively small refrigerant-to-water heat exchangers that can be added to a heat pump, air conditioner, or other refrigeration equipment, either at the factory or in the field. They heat water with 5 to 15% of the energy that would otherwise be given up by the system's condenser.[1, 15, 17] When properly applied, desuperheaters can provide high efficiency water heating. However, they provide water heating only when the system to which they are attached is operating. Backup water heating is needed at other times.

Achieving the Geothermal Heat Pump Consortium's (GHPC) goal of 400,000 annual GeoExchange installations each year by 2001 will reduce U.S. greenhouse emissions by over 1 million metric tons of carbon each year relative to base case market projections. This reduction in carbon emissions is equivalent to taking over half a million cars off the road, or planting over a million acres of trees. A self-sustaining GeoExchange industry will cause U.S. annual carbon emissions to decrease by an additional 450,000 tons every year. That translates into a total annual carbon reduction of at least 5 million metric tons by the year 2010.[15] Secondly, achieving GHPC's goal of 400,000 installations per year by 2001 will save consumers over $420 million per year in energy bills. After that, annual energy savings will increase by an additional $170 million every year.[15]

Ground-source heat pumps also require less floor space than conventional heating and cooling systems. Because the exterior system (the ground coil) is underground, there are no space requirements for cooling towers or air-cooled condensers. In addition, the ground-coupling system does not necessarily limit future use of the land area over the ground loop. Interior space requirements are also reduced. There are no floor space requirements for boilers or furnaces, just the unitary systems and circulation pumps. Furthermore, many distributed ground-source heat pump systems are designed to fit in ceiling plenums, reducing the floor space requirement of central mechanical rooms. Compared with air-source heat pumps that use outdoor air coils, ground-source heat

pumps do not require defrost cycles or crankcase heaters and there is virtually no concern for coil freezing. Cooling tower systems require electric resistance heaters to prevent freezing in the tower basin, also not necessary with ground-source heat pumps.
It is generally accepted that maintenance requirements are also reduced. Geothermal/ground source heat pumps have fewer mechanical components, making them more reliable and less prone to failure. The ground loop has an expected life of over 50 years and requires no maintenance. Furthermore, ground source heat pumps eliminate the exterior fin-coil condensers of air-cooled refrigeration systems and eliminate the need for cooling towers and their associated maintenance and chemical requirements. This is a primary benefit cited by facilities in highly corrosive areas, such as near the oceans where salt spray can significantly reduce outdoor equipment life. In addition, ground source heat pumps do not require highly trained maintenance technicians. The units can be serviced by residential HVAC technicians. With no cooling tower or boiler, GHP maintenance costs are 10-22¢/SF/year, as opposed to 38-50¢ for the average conventional heating and cooling system. [2, 6, 14]

Ground-source heat pump technology offers further benefits: the need for supplemental resistance heaters is reduced compared with air-source heat pumps, no exterior coil freezing (requiring defrost cycles) such as that associated with air-source heat pumps, improved comfort during the heating season (compared with air-source heat pumps-the supply air temperature does not drop when recovering from the defrost cycle), significantly reduced fire hazard over that associated with fossil fuel-fired systems, reduced space requirements and hazards by eliminating fossil-fuel storage, and reduced

local emissions from those associated with other fossil fuel-fired heating systems.[1, 5] Another benefit is quieter operation, because ground source heat pumps have no outside air fans. Finally, ground source heat pumps are reliable and long-lived, because the heat pumps are generally installed in climate controlled environments and therefore are not subject to the stresses of extreme temperatures. Because of the materials and joining techniques, the ground-coupling systems are also typically reliable and long-lived. For these reasons, ground-source beat pumps are expected to have a longer life and require less maintenance than alternative more conventional technologies (See Figure 4)[23] Figure 4 contains a table that compares 1987 capital costs and efficiency ratings for selected commercial space heating equipment. The table also attempts to forecast capital and maintenance costs forward for the systems to the year 2015. System efficiency is noted in second column. The efficiency measurements vary by equipment type. Electric air-source and natural gas heat pumps are rated for heating performance using the Heating Seasonal Performance Factor (HSPF); natural gas and distillate furnaces are based on Annual Fuel Utilization Efficiency; ground-source heat pumps are rated on coefficient of performance; and boilers are based on combustion efficiency.

Figure 4 - Capital Cost and Efficiency Ratings of Selected Commercial Space Heating Equipment

Equipment Type	Vintage	Efficiency [2]	Capital Cost ($1987 per Mbtu/hour) [3]	Maintenance Cost ($1987 per Mbtu/hour) [3]	Service Life (Years)
Electric Heat Pump	Current Standard	6.8	$71.92	$2.10	12
	1998- typical	7.5	$77.18	$2.10	12
	1998- high efficiency	9.4	$96.47	$2.10	12
	2005- typical	8.0	$77.18	$2.10	12
	2005- high efficiency	9.5	$94.72	$2.10	12
	2015 - typical	8.5	$73.67	$2.10	12
	2015 - high efficiency	10.0	$91.21	$2.10	12
Ground-Source Heat Pump	1998- typical	3.4	$166.67	$1.35	20
	1998- high efficiency	4.0	$250.00	$1.35	20
	2005- typical	3.4	$145.83	$1.35	20
	2005- high efficiency	4.1	$225.00	$1.35	20
	2015- typical	3.8	$135.42	$1.35	20
	2015 -high efficiency	4.2	$197.92	$1.35	20
Electric Boiler	Current Standard	0.98	$16.48	$0.09	21
Packaged Electric	1995	0.93	$18.63	$3.29	18
Natural Gas Furnace	Current Standard	0.80	$9.21	$0.69	20
	1998- high efficiency	0.92	$11.12	$0.67	20
	2015 – typical	0.81	$9.21	$0.68	20
Natural Gas Boiler	Current Standard	0.80	$7.95	$0.26	25
	1998 - high efficiency	0.90	$11.49	$0.35	25
	2005- typical	0.81	$7.76	$0.26	25
	2005- high efficiency	0.90	$9.49	$0.30	25
Natural Gas Heat Pump	1998- engine driven	4.1	$229.17	$4.69	13
	2005- engine driven	4.1	$166.67	$3.65	13
	2005- absorption	1.4	$173.61	$4.17	15
Distillate Oil Furnace	Current Standard	0.81	$10.58	$0.69	15
	1998	0.83	$16.06	$0.69	15
	2000	0.86	$16.26	$0.69	15
	2010	0.89	$16.81	$0.69	15
Distillate Oil Boiler	Current Standard	0.83	$12.28	$0.06	20
	1998- high efficiency	0.87	$17.19	$0.06	20
	2005- typical	0.83	$12.16	$0.06	20
	2005- high efficiency	0.87	$16.45	$0.06	20

[1]Equipment listed is for the New England Census Division, but is also representative of the technology data for the rest of the U.S.
[2]Efficiency measurements vary by equipment type. Electric air-source and natural gas heat pumps are rated for heating performance using the Heating Seasonal Performance Factor (HSPF); natural gas and distillate furnaces are based on Annual Fuel Utilization Efficiency; **ground-source heat pumps** are rated on coefficient of performance; and boilers are based on combustion efficiency.
[3]Capital and maintenance costs are given in 1987 dollars.

1.4 Where to Apply Ground-Source Heat Pumps

Ground-source heat pumps are generally applied to air conditioning and heating systems, but may also be used in any refrigerant application. The decision whether to utilize a ground source heat pump system is driven primarily by economics. Almost any HVAC system can be designed using a ground source heat pump. The primary technical limitation is a suitable location for the ground-coupling system. The following list identifies some of the best applications of ground source heat pumps:[1, 14, 15, 17]

- Ground-source heat pumps are probably least cost prohibitive in new construction; the technology is relatively easy to incorporate. It can also be cost effective to replace an existing system at the end of its useful life.
- In climates with either cold winters or hot summers, ground source heat pumps can operate much more efficiently than air source heat pumps or other air conditioning systems. Ground source heat pumps are also considerably more efficient than other electric heating systems and, depending on the heating fuel cost, may be less expensive to operate than other heating systems.
- In climates characterized by high daily temperature swings, ground source heat pumps show superior efficiency. In addition, in climates characterized by large daily temperature swings, the ground-coupling system also offers some thermal storage capability, which may benefit the operational coefficient of performance.
- In areas where natural gas is not available or where the cost of natural gas or other fuel is high compared with electricity, ground source heat pumps are economical. They operate with a heating coefficient of performance in the range of 3.0 to 4.5, compared with conventional heating efficiencies in the range of 80% to 97%.

Therefore, when the cost of electricity (per Btu) is less than 3.5 times that of conventional heating fuels (per Btu), ground source heat pumps have lower energy costs.

- High natural gas or fuel oil costs will favor ground source heat pumps over conventional gas or fuel oil heating systems. High electricity costs will favor ground source heat pumps over air source heat pumps.
- In facilities where multiple temperature control zones or individual load control is beneficial, ground source heat pumps provide tremendous capability for individual zone temperature control because they are primarily designed using multiple unitary systems.
- In areas where drilling costs are low, vertical-loop systems may be especially attractive.
- In areas with a high soil moisture content or high ground-water level, the size of the ground- coupling system is reduced improving overall economics.

The initial cost of the ground source heat pump system is one of the prime barriers to the economics. In locations with a significant ground source heat pump industry infrastructure, such as Oklahoma, Louisiana, Florida, Texas, and Indiana, installation costs may be lower and the contractors more experienced. This, however, is changing as the market for ground source heat pumps grows.

CHAPTER 2

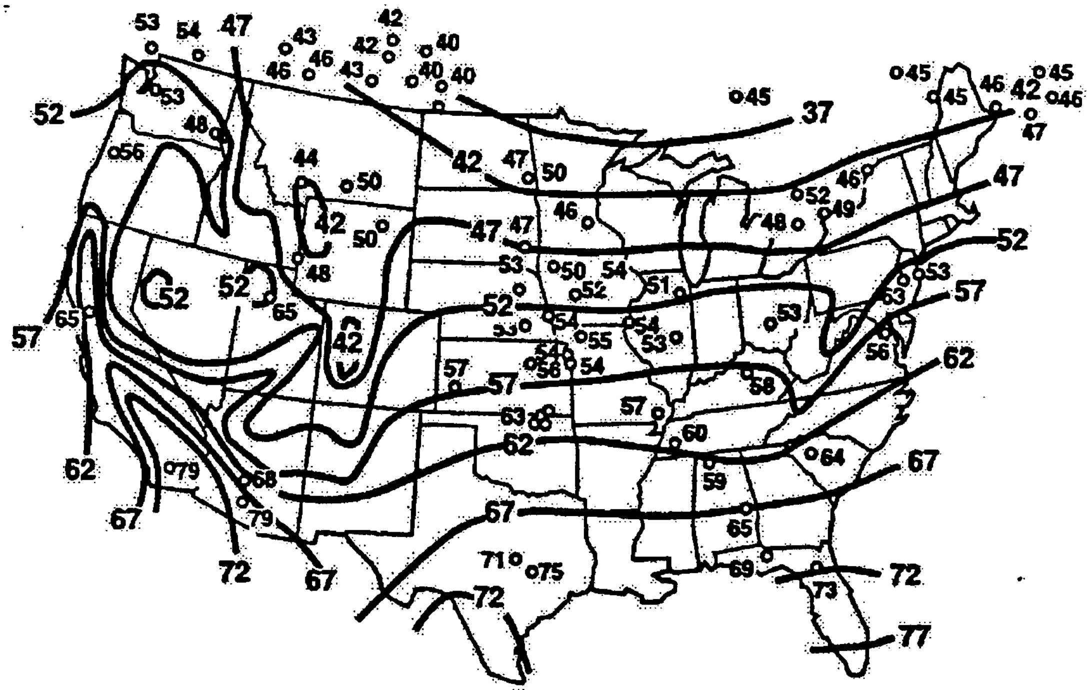
Variables Affecting Design and Performance

Among the variables that have a major impact on the sizing and effectiveness of a ground-coupling system, the importance of underground soil temperatures and soil type deserves special mention.

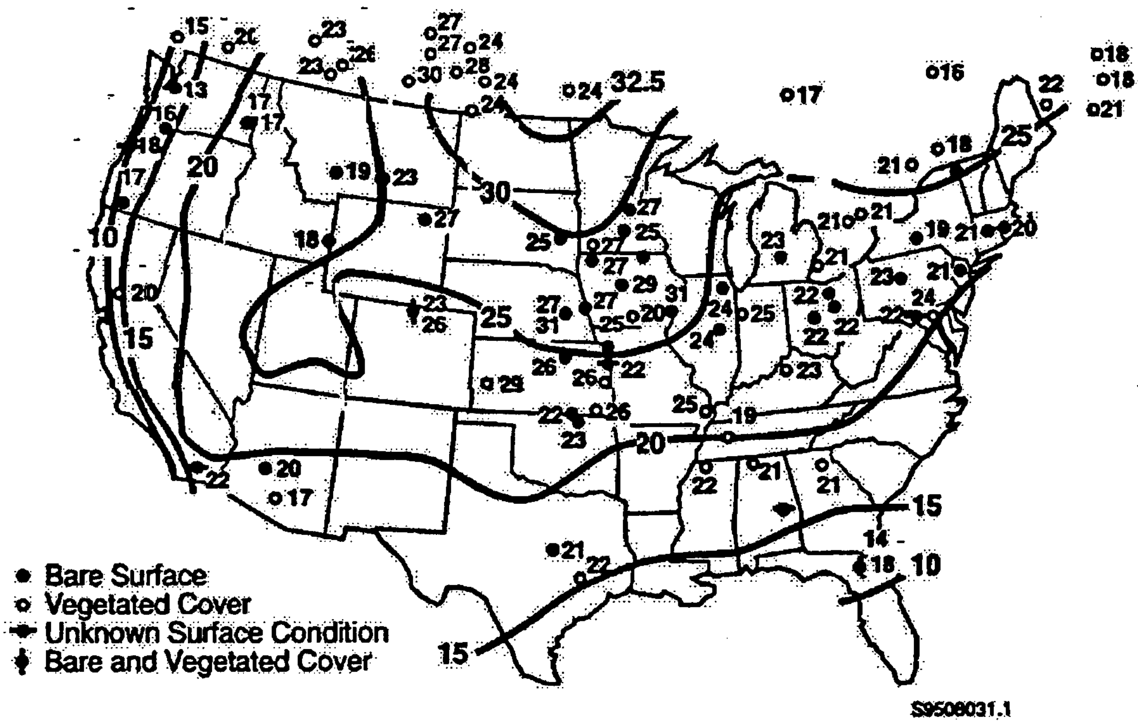
2.1 Underground Soil Temperature.

The soil temperature is of major importance in the design and operation of a ground source heat pump. In an open-loop system, the temperature of ground water entering the heat pump has a direct impact on the efficiency of the system. In a closed-loop system and in the direct-expansion system, the underground temperature will affect the size of the required ground-coupling system and the resulting operational effectiveness of the underground heat exchanger. Therefore, it is important to determine the underground soil temperature before selecting a system design.[1, 14, 17]

Annual air temperatures, moisture content, soil type, and ground cover all have an impact on underground soil temperature. In addition, underground temperature varies annually as a function of the ambient surface air temperature swing, soil type, depth, and time lag. Figure 5 contains a map of the United States indicating mean annual underground soil temperatures and amplitudes of annual surface ground temperature swings. Figure 6, though illustrating a specific location, illustrates how the annual soil temperature varies with depth, soil type, and season.[1]



(a) Mean earth temperature, T_M (°F)



(b) Earth surface temperature amplitude, A_S (°F)

Fig. 3. Mean Annual Soil Temperatures. Source: OSU (1988).

Figure 5

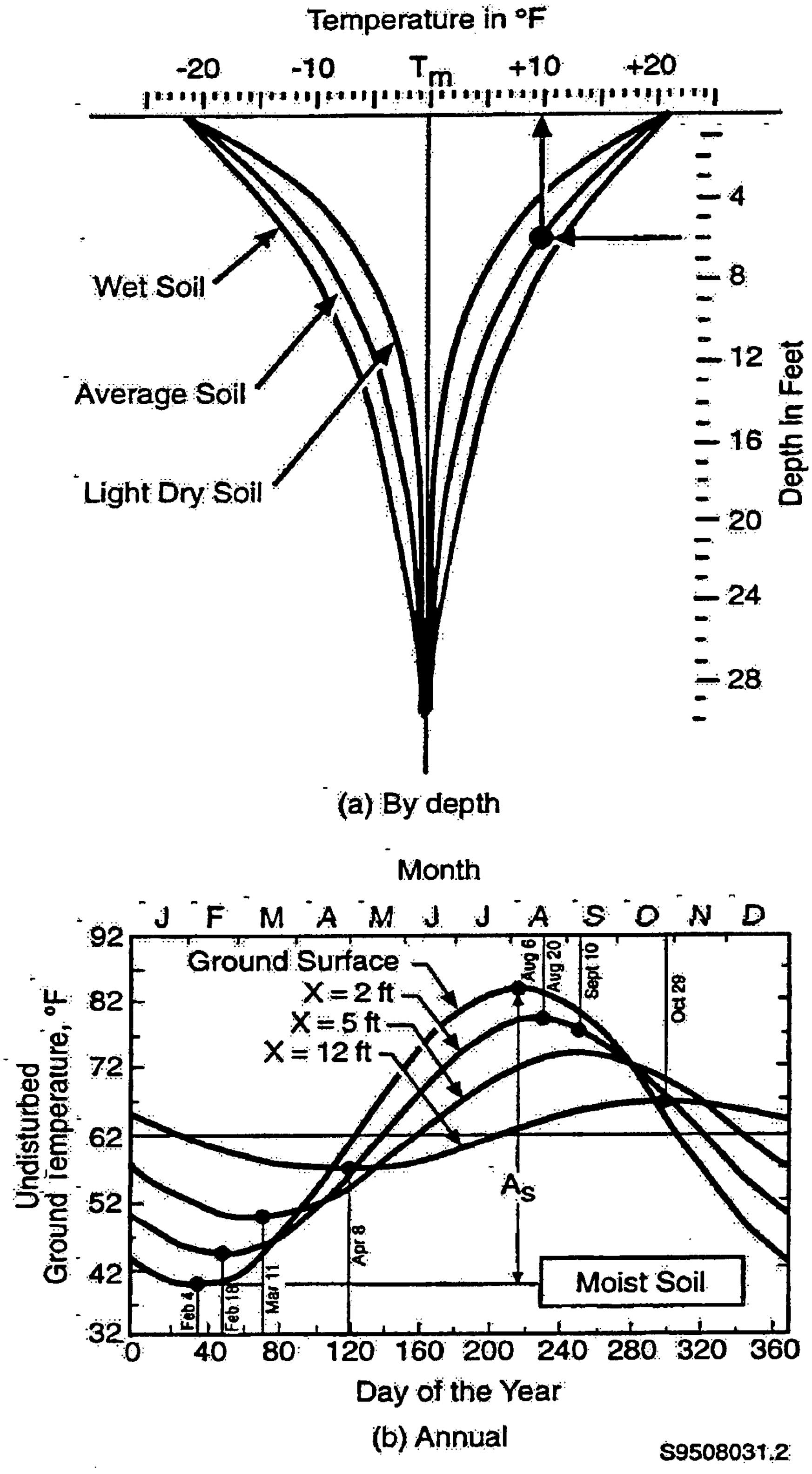


Fig. 4. Soil Temperature Variation. Source: OSU (1988).

Figure 6

2.2 Thermal Properties of the Soils

Probably no factor is more important to the design and successful operation of a closed-loop ground source heat pump system than the rate of heat transfer between the closed-loop ground-coupling system and the surrounding soil and rock. The thermal conductivity of the soil and rock is the critical value that determines the length of pipe required.[1, 13, 14] The pipe length, in turn, affects the installation cost as well as the operational effectiveness, which in turn affects the operating cost. Because of local variations in soil type and moisture conditions, economic designs may vary by location.

Soil classifications include coarse grained sands and gravels, fine grained silts and clays, and loam (equal mixtures of sand, silt, and clay). Rock classifications are broken down into nine different petrologic groups. Thermal conductivity values vary significantly within each of the nine groups. Each of these classifications plays a role in determining the thermal conductivity and thereby affects the design of the ground-coupling system. The following table indicates the properties of various soils.[14] The presence of moisture in the soil improves the heat transfer rate, and this element should be considered and taken into account.

Thermal Texture Class	Thermal Conductivity Btu/ft hr °F	Thermal Diffusivity ft^2 / day
Sand	0.44	.42
Silt	0.96	—
Clay	0.64	.50
Loam	0.52	.46
Saturated sand	1.44	.86
Saturated silt or clay	0.96	.61

The soil/field resistance to heat transfer must be considered in determining the loop pipe length.[13] This resistance varies with the pipe size and type, the soil type and dampness, the run time of the heat pump, and the configuration of the ground loop. Software is available for this calculation process, and is recommended since the process is tedious. Figure 7 shows thermal conductivity values for various substances and reiterates the importance of understanding the subsurface soil conditions prior to ground-couple system design. Figure 8 shows how thermal conductivity values relate to porosity and moisture content. Ground moisture improves thermal conductivity in all soil types. Therefore, high water tables improve ground source heat pump system efficiency and thus reduce the length of required piping for the ground-loop heat exchanger.

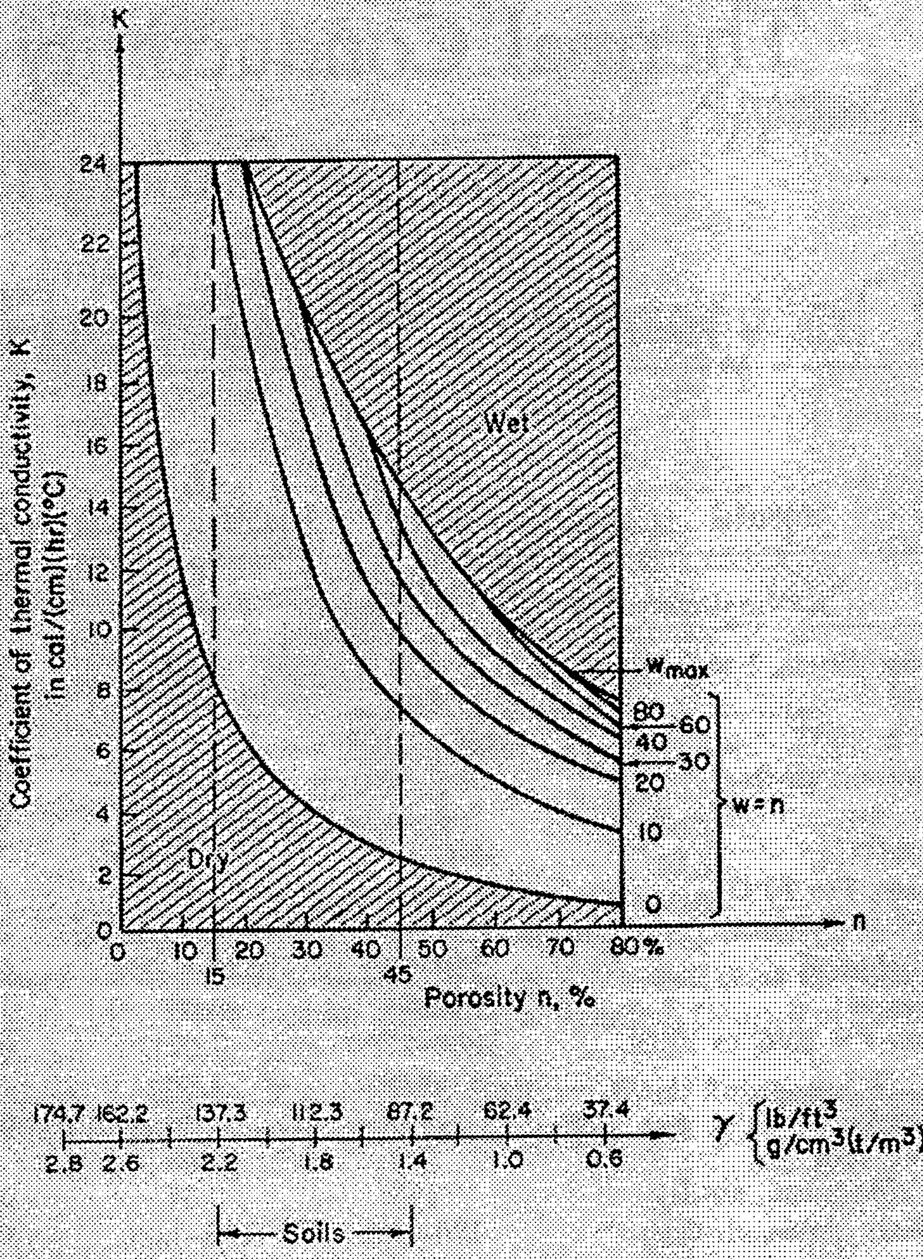
Thermal Conductivity of Various Substances

Comparison of Various Substances

Material	Unit Weight (kg/m³)	Thermal Conductivity K [Cal/(m)(hr)(°C)]	Heat Capacity C (Cal/kg)
1	2	3	4
Asbestos sheets, 1 to 5 mm thick	900	0.15	0.20
Asphalt	1800	0.65	–
Basalt, at 20°C	2400–3100	1.44	0.20
Ash, timber, air-dry	450–500	0.1–0.13	0.18
Cinder, dry	700–1000	0.06–0.25	0.18
Clay, at 0°C	1800–2600	2.83	0.224
Concrete, $T = 70°C$	–	0.77	0.156
Cork plates, natural	250	0.06	0.50
Felt, technical	150–250	0.04–0.05	0.45
Glass wool	200	0.05	–
Granite, $T = 20°C$ to $100°C$	2650–2700	7.32	0.20
Ice	900	1.90	0.50
Ice, −20°C	900	2.00	0.505
Mineral wool	200	0.06	–
Moss, sphagnum, air-dry	135	0.04	0.40
Peat moss plates, air-dry	170–250	0.05–0.06	0.50
air-dry	800–1000	0.26–0.40	0.39–0.87
Peat, pressed, moist	1140	0.59	0.39
Plywood	600	0.15	0.65
Sawdust, air-dry	150–250	0.05–0.08	0.60
Sand	1600–1800	1.70–2.10	0.20
Snow, loose	300	0.20	0.50
Snow, dense	500	0.50	0.50
Tarpaper	600	0.15–0.20	0.36
Topsoil	1800	1.00	–
Water	1000	0.50	1.00

231

Figure 7



Dependence of coefficient of thermal conductivity K of soil upon porosity n, unit weight γ_s, and moisture content w of soil after Krischer (see K. H. Seydel, Ref. 2 in Part III).

Figure 8

2.3 Ground-Coupled Heat Exchange System Designs

Series versus Parallel Flow

Closed-loop ground coupled heat exchangers may be designed in series, parallel, or a combination of both. In series systems, the heat transfer fluid can take only one path through the loop, whereas in parallel systems the fluid can take two or more paths through the circuit. The selection will affect performance, pumping requirements, and cost. Most large ground-coupling systems utilize both series and parallel flow systems. The advantages and disadvantages of series and parallel systems are summarized below.[1, 14] In large commercial systems, pressure drop and pumping costs need to be carefully considered or they will be very high. Variable-speed drives can be used to reduce pumping energy and costs during part-load conditions. Total life-cycle cost and design limitations should be used to design a specific system.

- Series-System Advantages: Single path flow and pipe size; easier air removal from the system; slightly higher thermal performance per linear foot of pipe because larger pipe size required in the series system.

- Series-System Disadvantages:

  Larger fluid volume of larger pipe in series requires greater antifreeze volumes; higher pipe cost per unit of performance; increased installed labor cost; limited capacity (length) due to Fluid pressure drop characteristics; larger pressure drop resulting in larger pumping load; requires larger purge system to remove air from the piping system.

- Parallel-System Advantages: Smaller pipe diameter has lower unit cost; lower volume requires less antifreeze; smaller pressure drop resulting in smaller pumping, load; lower installation labor cost.

- Parallel-System Disadvantages: Special attention required to ensure air removal and flow balancing between each parallel path to result in equal length loops.

CHAPTER 3

Department of Navy Geothermal System Implementation

3.1 Department of Navy Geothermal Projects

As Operation and Maintenance budgets shrink, the Department of Navy Shore Facilities Managers have had to implement means by which to do more with less. This trend of shrinking budgets is here to stay. For this reason, facility managers must remain poised and focused to work smarter by utilizing new, innovative, cost saving technologies. The utilization of Geothermal systems has proved to be a valuable heating and cooling technology for many shore facilities throughout the country. The benefits from installing Ground Source Heat Pump systems have been two fold. First, the systems have greatly reduced energy consumption and thus provided vast energy cost savings for shore facilities. Secondly, the systems greatly assist the Navy's energy and emissions reduction goals. Geothermal Systems have allowed shore facilities to take one large step forward in reaching the 30% energy and emissions reduction goal by the year 2005 and 2010 respectively, set by the Department of Navy (DON).

3.2 Project Successes

Eleven shore facilities have implemented Geothermal technologies to date. The numbers are increasing as word of the system success and benefits spreads through the Naval Facilities Engineering Command (NAVFAC) community. These eleven sites have installed in excess of 2,250 tons of geothermal systems and are paving the way the Navy heats and cools family housing units. While the majority of Ground Source Heat Pumps are being installed in family housing, the Navy is also exploring system implementation in larger commercial facilities. The following table, Table 1, lists the eleven Department

of Navy shore facilities that have implemented geothermal technologies:[16] Detailed Case Studies can be found in Appendix A.

DON GROUND SOURCE HEAT PUMP INSTALLATIONS

Location	Size/Application	Comment
Naval Air Station Pensacola, FL.	500 tons cooling for 236 family housing units	216 units installed. Retrofitted air source heat pumps. Gulf power provided $118K rebate and is metering results.
Naval Air Station Patuxent River, MD.	133 tons cooling for office bldg and 3 smaller bldgs.	Installed 1993.
CBC Gulfport, MS.	60 tons installed on Navy Exchange	Operational since 1998.
NAS Whiting Field, Milton, FL.	Installation on 323 housing units	Half are complete.
MCB Quantico, VA	215 tons installed on school and fire station.	Conversion from oil heating
Marine Corps Air Station, New River, Camp Lejeune, NC	200 tons on barracks	New construction.
Naval Security Group Activity, Chesapeake, VA	104 tons on 52 units	Competed FY96. Replaced air source heat pumps
Atlantic Division, Naval Facilities Engineering Command , Norfolk, VA	1 unit	Operational
Anacostia, Washington DC	40 tons	Operational on BOQ
Naval Observatory, Washington, DC	100 tons	Awarded for construction
Naval Air Station Oceana, and NAB Little Creek, VA	270 tons planned	DOE Super ESPC will be used. Contractor selected, MOU signed.

Table 1

The DON is the largest user of electrical energy in the nation. In 1998 the DON consumed 67,422,928 Mbtu.[20] Thus the DON spends $700,000,000/yr for energy costs of which $280,000,000/yr is spent for Military Family Housing.[15] These high annual expenditures represent an ever growing percentage of the Navy's operation and maintenance (O&M) budget. With the investment into geothermal technologies, particularly, Ground Source Heat Pumps, the Department of Navy has successfully reduced heating and cooling energy consumption within the subject facilities by 40%.

This 40% reduction in heating and cooling energy consumption equates to saving 58,629 Mbtu/yr or $626,429/yr. Assumptions made to arrive at these figures are: 1) 3.5 Tons of Capacity required for every 2,000 SF of conditioned space (571.43 SF/Ton)[3, 17], 2) 110.46 Mbtu/ksf per the Naval Facilities Engineering Service Center Energy Consumption Data[16, 20], 3) Energy Costs are $10.6847/Mbtu[15].

The utilization of geothermal technologies such as the Ground Source Heat Pumps have demonstrated the capability to provide huge energy costs savings within the Department of Navy. As the technology and its successes become more well known, facility managers will likely attempt to retrofit older heating and cooling systems with Ground Source Heat Pumps. This new technology will provide a valuable heating and cooling alternative that possess a remarkable ability to reduce energy consumption that translates into reduced energy costs for shore facilities.

CHAPTER 4

Economic/Feasibility Analysis

4.1 Ground Source Heat Pump Economics

The capacity of the heating and cooling system to be installed in a home is the same regardless of the type of system. The installed or "first" cost of a water-to-air (geothermal) heat pump, or air-to-air (conventional) heat pump, and a conventional gas, oil, or propane furnace with electric central air conditioning are all about the same.[14]

With the geothermal heat pump system, the additional cost is derived from installing the wells or the closed-loop system. If you have an adequate water supply, very little added investment may be needed. In most cases you will have to install a closed-loop or a well system. This cost can add $500 to $1,500 per ton of cooling capacity to the first cost.[14]

Vertical bores and loops typically install for $4 to $7 per foot in holes up to 150 or 200 feet deep. Depending on soil conditions, required bore lengths range from 125 feet per ton for cold climate, high initial load buildings to 300 feet per ton for warm climate installations. Polyethylene piping costs can be as low as $0.20 per foot of bore for 3/4 inch pipe and as high as $1.00 per foot of bore for 1 1/2 inch pipe.[14]

Drilling costs can range from $1.00 to $12.00 per foot. Typically $5.00 per foot is the upper limit for drilling the small holes required for geothermal heat pump systems, even in the most difficult systems. The larger pipe sizes result in shorter bore lengths. The average added cost for a vertical installation is approximately $950 per ton.[17]

Horizontal loop installations are placed in 4 to 6 foot deep trenches with pipe lengths running from 350 to 600 feet per ton, depending on soil conditions. Costs typically range from $.65 cents to $1.25 per foot of trench. The average added cost for a horizontal loop installation is about $650 per ton.

The added first cost can usually be justified in two ways. First, with longer equipment life, and second, with tax-free savings in operating costs over conventional systems. The industry estimates the median life of a water-source heat pump at 19 years compared to 10 years for an air-source heat pump or air conditioner.[14]

Thus, the annual ownership cost is lower. For example, if a conventional installation costs $4,000, the annual cost for its 10-year life is $400 per year. If a geothermal heat pump costs $7,000, the annual cost over its 19-year life is $368 per year. That's 8% lower than the conventional system.

The maintenance costs for geothermal systems are much less than that of conventional systems as discussed in Chapter 1, Section 1.3. Research has shown that maintenance costs for Ground Source Heat Pumps range from $.10 -.22/SF/yr compared to $.38 - .50/SF/yr for conventional systems. Reduced maintenance costs along with increased energy efficiency make Ground Source Heat Pumps a very attractive alternative.

4.2 Regional Annual Energy Cost Comparisons

The tables below show the typical annual energy costs for Ground Source Heat Pumps and conventional heating and cooling systems in various cities across the country. These tables will be utilized to approximate energy cost savings for Ground Source Heat Pumps in each of the various geographic regions of the United States. For the purpose of this report, the geographic regions are divided as follows: Northeast Region, Mid-Atlantic Region, Southeast Region, North Midwest Region, Southwest Region, and Northwest Region. The following regions will correlate with the specified Engineering Field Division (EFD) areas of responsibility.

Naval Facilities Engineering Field Division (EFD)	Acronym	Correlating Geographic Region
EFA Chesapeake	CHESDIV	Northeast Region
Atlantic Division	LANTDIV	Mid-Atlantic Region
Southern Division	SOUTHDIV	Southeast Region
Northern Division	NORTHDIV	North Midwest Region
Southwest Division	SOUTHWESTDIV	Southwest Region
EFA West	WESTDIV	Northwest Region
Pacific Division	PACDIV	Southwest Region

The costs shown are based on a well-insulated 2,000 SF 1-story home. The home has 3-bed rooms, 2-baths, with living room, dining room, family room, laundry room, and kitchen. Its indoor design dry bulb temperature is 70°F in winter and 75°F in summer. Typical weather conditions were used to calculate the cooling and heating loads, with some adjustments in the home construction representative of the weather area.

Northeast Region - Boston, MA

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	12,211	0	$733
	4.0 ton 2 speed	11,439	0	$686
Air-Air	12 SEER	21,089	0	$1,265
	14 SEER	19,700	0	$1,182
Gas	80%/10 SEER	4,358	1,465	$1,141
	90%/12 SEER	4,035	1,261	$999
Propane	80%/10 SEER	4,358	1,593	$1,855
	90%/12 SEER	4,035	1,371	$1,614
Oil (W/elecDHW)	80%/10 SEER	10,244	805	$1,420
	80%/12 SEER	9,921	805	$1,400

Table 2

Mid-Atlantic Region - Richmond, VA

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	9,829	0	$590
	4.0 ton 2 speed	8,893	0	$534
Air-Air	12 SEER	18,465	0	$1,108
	14 SEER	17,093	0	$1,026
Gas	80%/10 SEER	6,550	1,095	$1,050
	90%/12 SEER	6,006	944	$927
Propane	80%/10 SEER	6,550	1,192	$1,585
	90%/12 SEER	6,006	1,027	$1,387
Oil (W/elecDHW)	80%/10 SEER	11,567	575	$1,269
	80%/12 SEER	11,023	575	$1,236

Table 3

Southeast Region - Tampa, FL

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	10,362	0	$622
	4.0 ton 2 speed	8,979	0	$539
Air-Air	12 SEER	19,151	0	$1,149
	14 SEER	16,744	0	$1,005
Gas	80%/10 SEER	14,589	453	$1,147
	90%/12 SEER	13,277	410	$1,043
Propane	80%/10 SEER	14,589	493	$1,368
	90%/12 SEER	13,277	446	$1,043
Oil (W/elecDHW)	80%/10 SEER	18,566	164	$1,278
	80%/12 SEER	17,254	164	$1,199

Table 4

North Midwest Region - Detroit, MI

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	13,346	0	$801
	4.0 ton 2 speed	12,597	0	$756
Air-Air	12 SEER	23,789	0	$1,427
	14 SEER	22,240	0	$1,334
Gas	80%/10 SEER	4,941	1,627	$1,273
	90%/12 SEER	4,576	1,404	$1,117
Propane	80%/10 SEER	4,941	1,770	$2,066
	90%/12 SEER	4,576	1,528	$1,802
Oil (W/elecDHW)	80%/10 SEER	10,793	920	$1,568
	80%/12 SEER	10,428	920	$1,546

Table 5

South Midwest Region - Houston, TX

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	9,312	0	$559
	4.0 ton 2 speed	8,236	0	$494
Air-Air	12 SEER	18,427	0	$1,106
	14 SEER	16,352	0	$981
Gas	80%/10 SEER	11,308	673	$1,082
	90%/12 SEER	10,307	588	$971
Propane	80%/10 SEER	11,308	732	$1,411
	90%/12 SEER	10,307	639	$1,258
Oil (W/elecDHW)	80%/10 SEER	15,520	311	$1,242
	80%/12 SEER	14,519	311	$1,182

Table 6

Southwest Region - Los Angeles, CA

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	7,762	0	$466
	4.0 ton 2 speed	7,077	0	$425
Air-Air	12 SEER	14,914	0	$895
	14 SEER	13,869	0	$832
Gas	80%/10 SEER	4,018	992	$836
	90%/12 SEER	3,697	839	$725
Propane	80%/10 SEER	4,018	1,079	$1,320
	90%/12 SEER	3,697	913	$1,135
Oil (W/elecDHW)	80%/10 SEER	8,769	518	$1,044
	80%/12 SEER	8,448	518	$1,025

Table 7

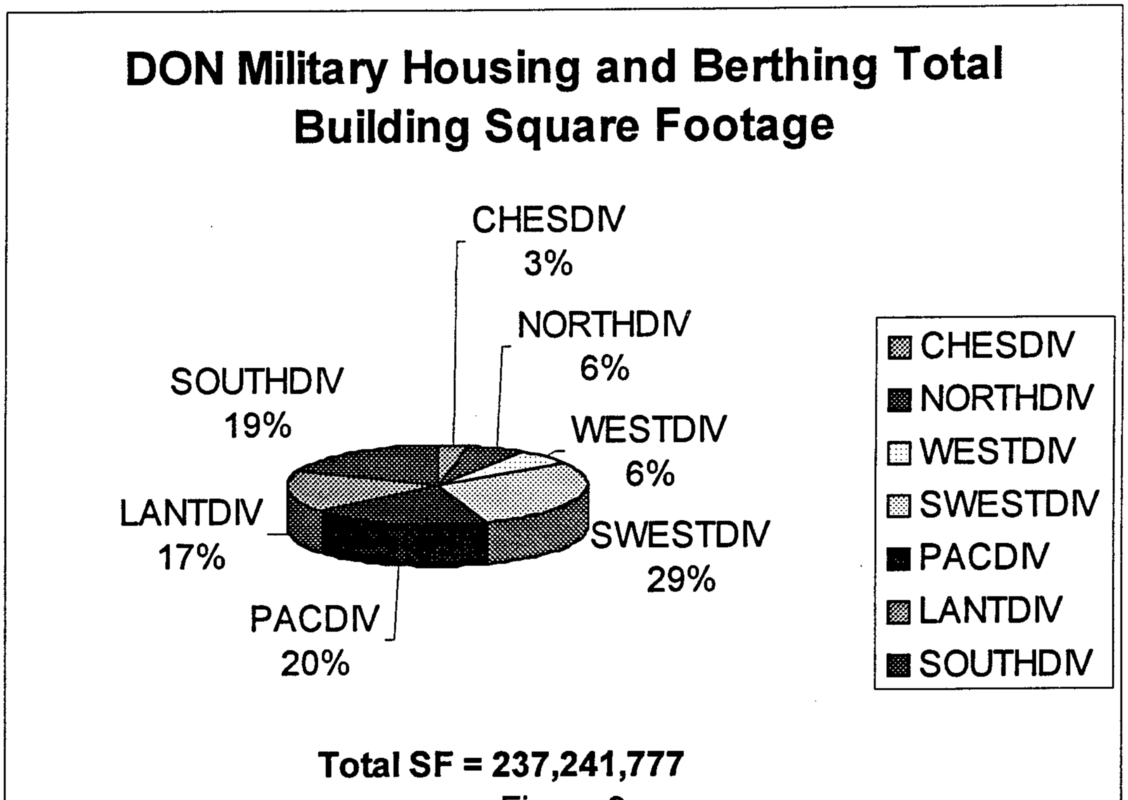
Northwest Region - Portland, OR

System Type	Efficiency	Total Annual		Sample Annual Costs
		kWh	Ccf/gal	6¢/ kWh; 60¢/ ccf; $1.00/gal
Geothermal	3.5 ton 1 speed	10,790	0	$647
	4.0 ton 2 speed	9,918	0	$595
Air-Air	12 SEER	18,362	0	$1,102
	14 SEER	17,543	0	$1,053
Gas	80%/10 SEER	2,834	1,461	$1,047
	90%/12 SEER	2,649	1,348	$968
Propane	80%/10 SEER	2,834	1,589	$1,759
	90%/12 SEER	2,649	1,354	$1,513
Oil (W/elecDHW)	80%/10 SEER	8,366	818	$1,320
	80%/12 SEER	8,181	818	$1,309

Table 8

4.3 DON Family Housing Square Footage/Energy Consumption Data

The Department of the Navy has 237,241,777 SF of family housing and berthing space that it maintains within the United States and military bases abroad (Figure 9). This large inventory of Navy facilities accounts for 40% of the 67,422,928 Mbtu annual energy consumption within the DON (Figure 10). The Navy is the largest user of electricity in the nation with an annual energy expenditure of nearly $700,000,000 (Figure 11). A breakdown of annual military housing and berthing energy costs by EFD is shown in Figure 12.


DON Military Housing and Berthing Total Building Square Footage
CHESDIV 3%
NORTHDIV 6%
WESTDIV 6%
SWESTDIV 29%
PACDIV 20%
LANTDIV 17%
SOUTHDIV 19%
CHESDIV
NORTHDIV
WESTDIV
SWESTDIV
PACDIV
LANTDIV
SOUTHDIV
Total SF = 237,241,777
Figure 9

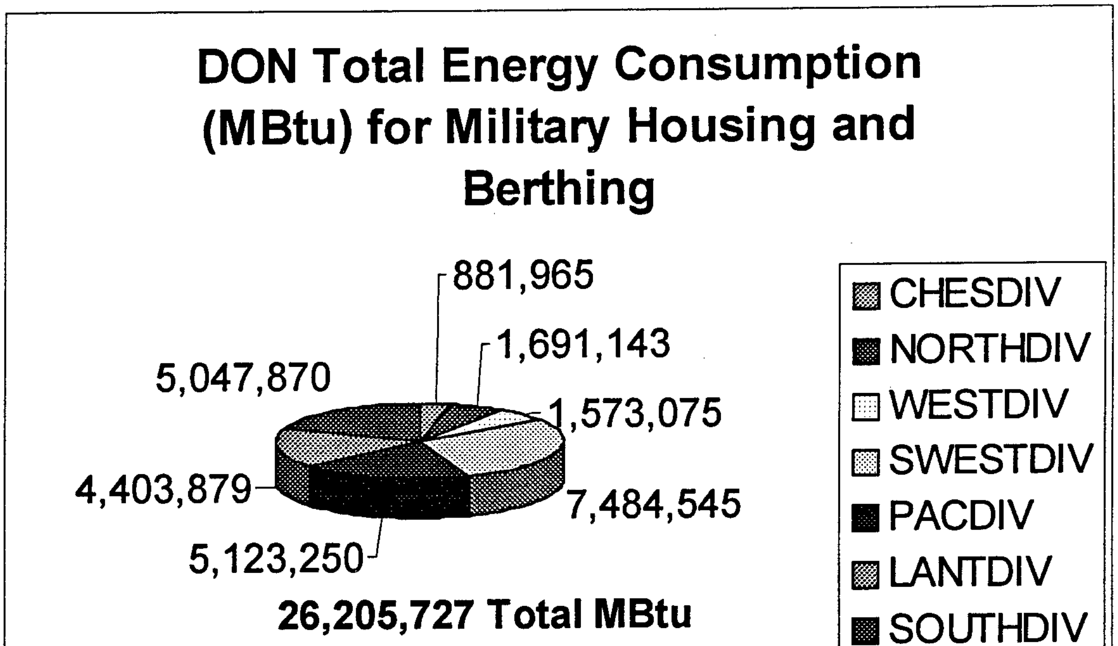


Figure 10

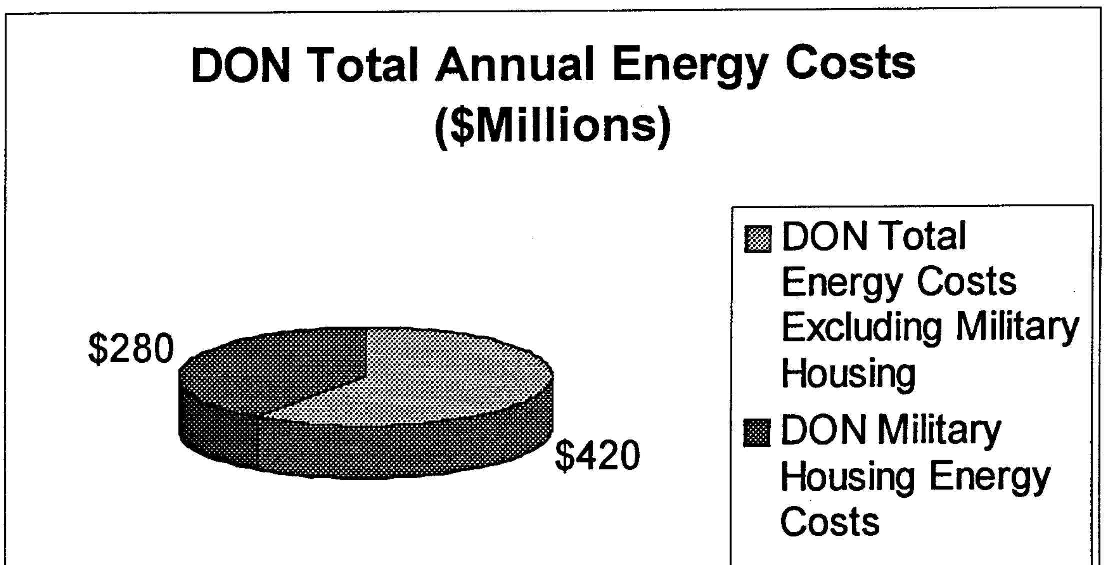


Figure 11

DON Military Housing and Berthing Total Annual Energy Costs

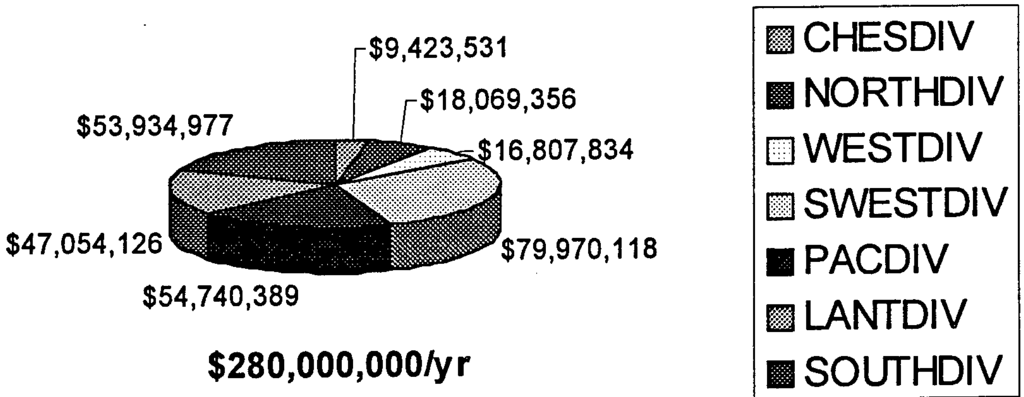


Figure 12

The Naval Facilities Engineering Command has the responsibility of overseeing all Navy facility assets. These assets are managed by Engineering Field Divisions (EFD) that oversee assets in particular geographic regions of the United States, as well as overseas assets in Europe, the Pacific rim and Japan. Atlantic Division's (LANTDIV) region consists of the Mid-Atlantic and Europe while the Pacific Division (PACDIV) manages assets in the Pacific Ocean region including Hawaii, Guam and Japan.

This large inventory of military housing results in large energy expenditures that continue to consume an ever-increasing percentage of the Operation and Maintenance budget. This large expenditure provides the Navy with a great opportunity to implement new energy savings technologies. Ground Source Heat Pumps, being one of these increasingly used technologies, provides a great opportunity for Navy facilities managers to reduce energy consumption and lower energy costs.

4.3 Life Cycle Cost Analysis

The Life Cycle Cost Analysis was conducted by calculating the all costs as a cost per square foot of conditioned space. The costs utilized included the following:

- Initial Cost – Cost of Construction (Purchase and Installation)

  Assumption: Standard 2000 SF residence requires 3.5 Ton of Capacity

  Air – Air System = $4000 for Std. 2000 SF Home = $2.00/SF

  Geothermal (GSHP) = Heat Pump/Equipment Costs are comparable; cost increase realized due to the Ground Loop Heat Exchange System = $1000/Ton = $1.75/SF + $2.00/SF = $3.75/SF

  Note: All calculations were made with average vertical loop installation cost. The cost of the ground loop heat exchanger will vary with location and associated soil conditions as well as with the type of ground loop heat exchanger installed.

- Maintenance Cost

  Average Maintenance Cost per SF

  Air – Air = $.44/SF

  Geothermal (GSHP) = $.16/SF

  Note: The average maintenance costs have been adjusted to account for labor cost variances within the different geographic regions of the United States. These labor adjustments are based upon regional labor cost data pulled from the Department of Labor and Bureau for Labor Statistics.[24] These costs will vary and fluctuate with the general regional labor markets.

- Energy Cost

Energy costs utilized are based on the Regional Annual Energy Cost Comparisons for the different geographic regions of the United States. These Cost Comparisons are shown as Tables 2 – Table 8 in Section 4.2. All calculations are based upon comparing an Air –Air system with a 14 SEER and the 3.5 ton 1 Speed Geothermal Unit. When Geothermal units are compared to other conventional systems such as gas, oil or propane, the energy savings for the geothermal system is further improved. This represents the most conservative energy cost comparison and most accurately portraits the vast majority of the current heating and cooling systems installed in military family housing today.

- Replacement Cost (Equipment Replacement at the end of useful life)

When comparing equipment costs for geothermal vs. conventional systems the additional geothermal system cost arises due to the ground-loop heat exchanger. The ground-loop heat exchangers have a life of greater than 50 years and thus add no expense to the replacement cost figure over the 50 year study period. The heat pump and distribution systems are very similar and have like costs. Therefore, the equipment replacement costs are calculated as the same at $2.00/SF.

Note: The difference and major benefit for the geothermal system is the extended equipment life. Geothermal equipment life greatly exceeds the conventional heat pump, which is located outdoors, exposed to the elements, whereas geothermal heat pumps are installed indoors, out of the elements, free from the harmful effects of corrosion.

Other assumptions made when calculating the Present Value and Life Cycle Cost savings where:

- 8% Discount Rate (Interest Rate) – Used for all Time Value of Money (TVM) calculations
- 50 Year Life Cycle Cost Analysis Study Period
- No financing costs – Initial Project Funds available

The Life Cycle Cost Analysis details the life cycle cost savings by geographic region and EFD area of responsibility (Table 9). Annual energy and emissions reduction figures are displayed in (Table 10).

Life Cycle Cost Analysis
Ground Source Heat Pumps vs. Conventional Air-Air Heat Pumps
DON Military Housing & Berthing

Analysis conducted for each Geographic Region

EFD	Correlating Geographic Region	Military Housing & Berthing Building Square Footage	Costs/SF Initial Cost	Costs/SF Maint. Cost	Costs/SF Energy Cost	Replacement Cost	Years Equip. Life	Years Study Period	Present Value	Life Cycle Cost Savings	Payback (Yrs)
EFA Chesapeake	**Northeast**										
Geothermal		7,984,478	$3.75	$0.16	$0.37	$2.00	19	50	$85,953,501	$41,077,333	3.47
Air - Air		7,984,478	$2.00	$0.44	$0.59	$2.00	12	50	$127,030,833		
Atlantic Division	**Mid-Atlantic Region**										
Geothermal		39,868,719	$3.75	$0.14	$0.30	$2.00	19	50	$384,563,896	$182,431,843	3.82
Air - Air		39,868,719	$2.00	$0.38	$0.51	$2.00	12	50	$566,995,738		
Southern Division	**Southeast Region**										
Geothermal		45,698,856	$3.75	$0.14	$0.31	$2.00	19	50	$449,744,514	$194,295,061	4.06
Air - Air		45,698,856	$2.00	$0.38	$0.50	$2.00	12	50	$644,039,576		
Nothern Division	**North Midwest Region**										
Geothermal		15,309,947	$3.75	$0.17	$0.40	$2.00	19	50	$173,053,330	$88,503,198	3.14
Air - Air		15,309,947	$2.00	$0.46	$0.67	$2.00	12	50	$261,556,528		
Southwest Divisio	**Southwest Region**										
Geothermal		67,758,052	$3.75	$0.16	$0.23	$2.00	19	50	$618,764,430	$322,481,507	3.70
Air - Air		67,758,052	$2.00	$0.45	$0.42	$2.00	12	50	$941,245,937		
EFA West	**Northwest Region**										
Geothermal		14,240,523	$3.75	$0.18	$0.32	$2.00	19	50	$149,293,592	$73,001,179	3.48
Air - Air		14,240,523	$2.00	$0.48	$0.53	$2.00	12	50	$222,294,771		
Pacific Division	**Southwest Region**										
Geothermal		46,381,202	$3.75	$0.19	$0.32	$2.00	19	50	$491,921,139	$260,459,159	3.22
Air - Air		46,381,202	$2.00	$0.53	$0.53	$2.00	12	50	$752,380,298		
							Total Life Cycle Cost Savings Potential			**$1,162,249,279**	

Table 9

Annual Energy and Emissions Reductions
Ground Source Heat Pumps vs. Conventional Air-Air Heat Pumps
DON Military Housing & Berthing

Analysis conducted for each Geographic Region

EFD	Correlating Geographic Region	Military Housing & Berthing Building Square Footage	Total Annual kwh/SF	Total Annual kwh Consumption	Annual Energy Savings (kwh)	Annual Mbtu Reduction	Annual Mbtu Reduction/SF	Annual Reduction in Greenhouse Emissions (Metric Tons)
EFA Chesapeake	**Northeast**							
Geothermal		7,984,478	6.11	48785161	29861948	101988	0.0128	2196
Air - Air		7,984,478	9.85	78647108				
Atlantic Division	**Mid-Atlantic Region**							
Geothermal		39,868,719	4.91	195755410	145122137	495636	0.0124	10964
Air - Air		39,868,719	8.55	340877547				
Southern Division	**Southeast Region**							
Geothermal		45,698,856	5.18	236720074	145779351	497880	0.0109	12567
Air - Air		45,698,856	8.37	382499425				
Nothern Division	**North Midwest Region**							
Geothermal		15,309,947	6.67	102117346	68129264	232682	0.0152	4210
Air - Air		15,309,947	11.12	170246611				
Southwest Division	**Southwest Region**							
Geothermal		67,758,052	3.88	262901242	206662059	705813	0.0104	18633
Air - Air		67,758,052	6.93	469563300				
EFA West	**Northwest Region**							
Geothermal		14,240,523	5.40	76898824	47990563	163902	0.0115	3916
Air - Air		14,240,523	8.77	124889387				
Pacific Division	**Southwest Region**							
Geothermal		46,381,202	3.88	179959064	141462666	483138	0.0104	12755
Air - Air		46,381,202	6.93	321421730				
				Totals	**785007987**	**2681038**		**65241**

Table 10

4.5 Summary – Economic and Environmental Benefits

As the Navy cruises into the 21st Century, many initiatives will be implemented to reduce Government expenditures and improve environmental stewardship. Both initiatives are important to the continued success of the Department of the Navy. As the purse strings tighten and budgets become smaller, facilities managers must strive to find ways to cut costs and make the dollar go further. At the same time, the DON has taken the lead to improve environmental stewardship through actions that will improve and maintain our land, air and water. Currently several initiatives are in place to guide the DON in the right direction. First is the DON Energy Reduction Goal (Figure 13). The DON target is to reduce energy consumption 30% by 2005 using FY85 as the baseline. Second, is the DON Carbon Emissions Reduction Goal (Figure 14). The DON target is to reduce carbon (carbon equivalents) emissions 30% by 2010 using FY90 as the baseline. These initiatives are currently on schedule to meet their goals; however, continued efforts to reduce energy consumption and harmful emissions are paramount to meeting the ultimate goals.

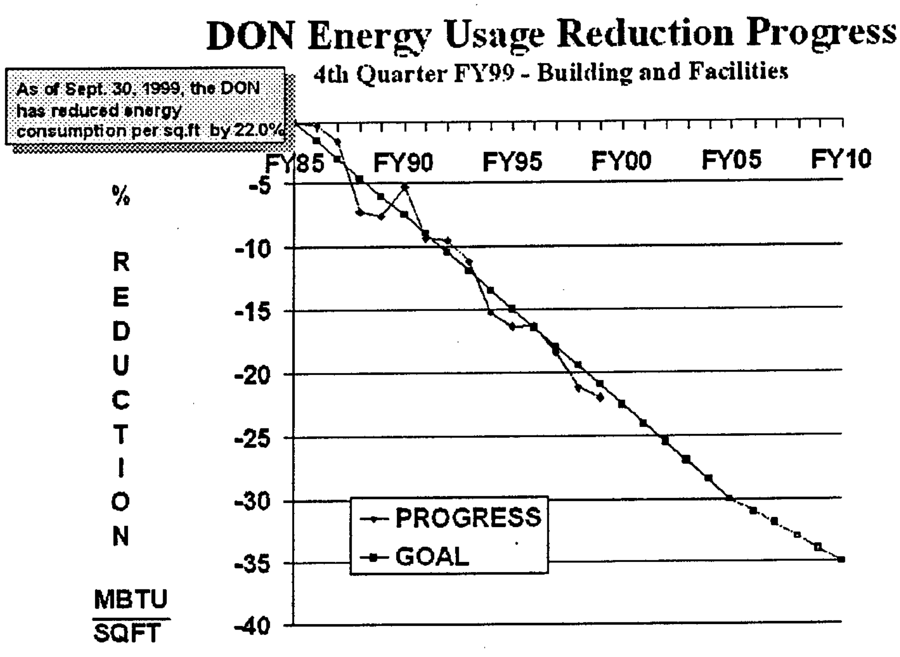
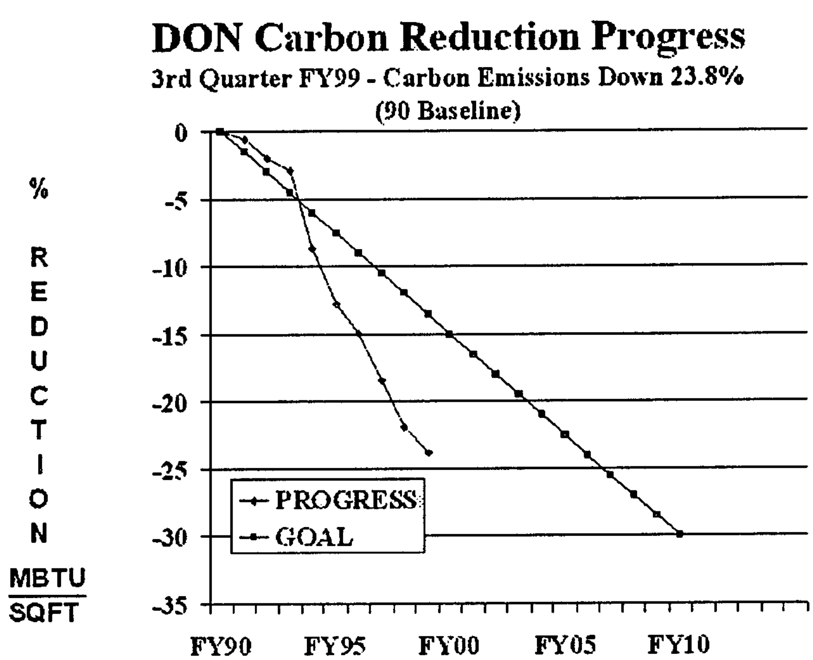


Figure 13

Figure 14



The Life Cycle Cost Analysis shows that Ground Source Heat Pumps provide an exceptional opportunity to the DON to help meet these ongoing initiatives. Based upon the analysis, Ground Source Heat Pumps provide exceptional value to the Department of the Navy and have the potential for a DON wide Life Cycle Cost Savings of $1,162,249,279 over a 50 year study period. Through implementation of Ground Source Heat Pumps in all DON military housing and berthing facilities, the Navy has the potential to reduce annual energy consumption by 785,007,987 kwh or 2,681,038 Mbtus. In addition to reducing energy consumption and greatly reducing energy costs, geothermal technologies decreases the greenhouse gas emissions of carbon dioxide, sulfur dioxide and nitrogen oxides by up to 44% compared to air source heat pumps.[3] Based upon EPA research and studies, each normally sized residential Ground Source Heat Pump (3.5 Ton Capacity) installed will reduce annual greenhouse emissions by nearly .55 metric tons of carbon equivalents.[5] These emissions reductions prevent ozone layer destruction by using factory sealed refrigeration systems that will seldom or never have to be recharged and Ground Source Heat Pumps typically use less refrigerant than conventional air conditioning systems. These factors reduce leak potential from field connections and increases reliability.[3] Ground Source Heat Pumps also eliminate fossil fuel burning systems, further reducing harmful emissions. Through implementation of Ground Source Heat Pumps in all DON military housing and berthing facilities, the Navy has the potential to reduce annual greenhouse emissions by 65,241 metric tons.

CONCLUSION

At first glance, Geothermal technologies have an enormous upside potential for wide spread utilization within family housing and berthing facilities around the United States and the world. Ground Source Heat Pumps do not represent a new fade or untested technology. The technology has been around for over half a century and has been further refined until it now represents one of the most economical heating and cooling systems on the market today.[1] The Navy as well as the private sector have started to discover this under utilized technology. The number of Ground Source Heat Pump units installed have increased to over 35,000 reported units per year and continues to grow.

The enormous benefits produced by this technology make it a sound economic investment for DON facilities. Implementation of Ground Source Heat Pumps in DON Military Housing and berthing facilities has the potential to reduce energy consumption by 785,007,987 kwh/yr saving $47,100,479/yr in DON energy costs. Ground Source Heat Pumps not only reduce energy consumption, which translates into lower energy costs but, it also reduces system maintenance costs further extending its advantage over conventional heating and cooling systems. Finally, Ground Source Heat Pumps reduce harmful emissions that cause damage to the ozone layer and degrade air quality. Greater implementation of Geothermal technologies will position the DON favorably to lead the way in reducing harmful emissions thus continuing its commitment to improved environmental stewardship.

RECOMMENDATION

Based upon the initial review of Ground Source Heat Pumps and the information contained in this research paper, I would recommend that the DON seek increased implementation of Ground Source Heat Pumps for Military Family Housing and berthing facilities. The ability to do more with less and to stretch the ever shrinking facilities O&M budgets will be key to the success of the Civil Engineer Corps and the Navy in the years ahead. Ground Source Heat Pump technology provides an opportunity to greatly reduce energy and maintenance costs while providing high quality heating and cooling to DON facilities. Savings realized by the implementation of Ground Source Heat Pumps will allow facility managers and the Civil Engineer Corps greater flexibility to address the ever increasing burden of maintaining the aging facilities at DON bases here and abroad.

Facilities Managers should look to obtain energy funds that are available to support projects that can provide a payback of 10 years or less. This technology has the ability to provide that type of payback and should be aggressively sought. These projects can also be funded by housing MILCON funds or via new cooperative ventures with regional utility companies. This type of cooperative arrangement has been utilized successfully at several Department of Defense facilities and provides yet another avenue to fund and implement this technology. The bottom line is that Geothermal technology has great potential to reduce energy and decrease DON energy costs; however, in order to achieve these benefits up front project funding must be secured. Funding by far represents the largest challenge to rapid system implementation.

The Navy should also look into utilization of Geothermal technologies for facilities other than family housing and berthing. This technology can be utilized in residential units as well as larger buildings such as operational and administrative facilities. The more building square footage heated and cooled by Geothermal technology, the higher the return through reduced energy consumption and lower maintenance costs. Geothermal technologies possess an opportunity to change the way we heat and cool facilities with incredible upside potential. Using an analogy, this is one boat that the Department of the Navy can't afford to miss.

REFERENCES

1. US Department of Energy, Federal Technology Alert, Ground-Source Heat Pumps Applied to Commercial Facilities, September 1995

2. Cane, D., "Survey and Analysis of Maintenance and Service Costs in Commercial Building Geothermal Systems, Geothermal Heat Pump Consortium, 1998

3. Pamphlet, "Geothermal Heat Pumps Make Sense for Homeowners", U.S. Department of Energy, Office of Geothermal Technologies, September 1998

4. Pamphlet, "Using the Earth to Heat and Cool Buildings", U.S. Department of Energy, May 1996

5. Pamphlet, "Environmental and Energy Benefits of Geothermal Heat Pumps", U.S. Department of Energy, Office of Geothermal Technologies, September 1998

6. Pamphlet, " Geothermal Heat Pumps", U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, September 1998

7. Pamphlet, "Introducing Geothermal Heat Pumps", US Environmental Protection Agency, December 1996

8. Penton Research Services, "An Accurate Estimate of Calendar Year 1997 Geothermal Heating and Cooling Installations, and a Tracking of Installations Made in 1995 to 1997", March 1998

9. Brochure, Geothermal Heat Pumps for Commercial Applications", International Ground Source Heat Pump Association, May 1995

10. Pamphlet, "Geothermal Heat Pumps for Medium and Large Buildings", U.S. Department of Energy, Office of Geothermal Technologies, September 1998

11. Brochure, "There's An Underground Movement Towards Greater Energy Efficiency", U.S. Department of Energy

12. Cane, D., "Analysis of Existing Geoexchange Installation Data Sets", Geothermal Heat Pump Consortium, 1997

13. Allen, M. L. and Philippacopoulos, A. J., "Thermally Conductive Cementitious Grouts for Geothermal Heat Pumps", Geothermal Heat Pump Consortium, November 1998

14. Alliant Geothermal Information Office at http://www.alliantgeo.com

15. GeoExchange – Geothermal Heat Pump Consortium, Inc., http://www.geoexchange.org

16. Naval Facilities Engineering Service Center Web Page at http://www.nfecs.navy.mil

17. International Ground Source Heat Pump Association Web Page at http://www.igshpa.okstate.edu

18. U.S. Department of Energy Web Page at http://www.doe.gov

19. Naval Facilities Engineering Service Center, NAVFAC Publication P-164, September 30, 1998

20. Naval Facilities Engineering Service Center Newsletter, Energy News, "Naval Activity Energy Consumption for Apr 97 – Mar 98", July/September 1998

21. Bose, Jason, "Pitfalls to Avoid when Installing Geothermal Energy Systems", Contracting Business Magazine, 1997

22. Environmental Protection Agency, "Space Conditioning: The Next Frontier", Office of Air and Radiation, April 1993

23. Department of Energy Annual Energy Outlook, http:www.eia.doe.gov/oiaf/aeo/assumption/tbl13.html

24. Bureau of Labor Statistics Web Page http://stats.bls.gov

25. Telephone interview with Mr. Keith Swilley, District Marketing Manager, Gulf Power Company on February 01, 2000

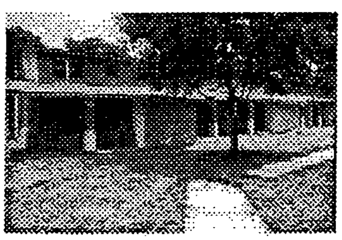
26. Telephone interview with Mr. Pete Hill, Naval Facilities Engineering Service Center, Director on January 28, 2000

27. Telephone interview with Mr. Glenn White, Energy Manager, Naval Air Station, Whiting Field on February 01, 2000

Case Study

Lighthouse Terrace Housing, Pensacola NAS, Florida

Project



Already tight on funds for military family housing, Pensacola Naval Air Station (NAS) housing personnel knew that the natural gas lines serving a housing complex scheduled for renovation were deteriorating and would need to be replaced. They met with Gulf Power to determine if their was any way to reduce renovation and energy costs. After a lot of hard work and persistence by Navy and utility personnel, GeoExchange proved to be the answer.

Lighthouse Terrace is a military family housing complex at the Pensacola Naval Air Station that includes 236 residential apartments ranging from two to four bedroom each. The units are arranged in a townhouse configuration. Four to six units are grouped in a single building — the three- and four-bedroom apartments are housed four units per building and six of the smaller, two-bedroom apartments are incorporated into a building.

Renovation Innovation

"Basically what we did was to gut the entire building -- the only thing left standing were stud walls and concrete foundation," says NAS Pensacola Housing Director Ms. Rudy Weber. Wall and attic insulation were replaced. Low-flow shower heads "that actually work" were included in the package of energy conservation measures that the units received. Existing windows and doors were replaced with energy-efficient models.

"Probably one of the things that we are most proud of is our geothermal system," says Ms. Weber. "Initially the project was designed to replace the gas furnace that was already in the unit. However, we seem to continually have problems if we have a gas outage. We generally are required to pay someone overtime to come back out and light pilot lights. We have to worry about deteriorated gas mains."

"Gulf Power offered us a $500 rebate per housing unit for a grand total of $118,000 which would allow us to proceed with the geothermal installation," said Ms. Weber. "That's how we have gotten to where we're at now -- with the support of Gulf Power, working with the Navy, looking at how much energy we would save in the future. Not only energy savings, but maintenance savings" figured prominently in the Navy's decision to go with GeoExchange.

Utility Assistance

When the Navy base decided to renovate the housing complex, they called in Gulf Power to make recommendations on the most energy-efficient measures and practices. "We came in and calculated their heating and cooling needs for these units and helped them understand their energy loading needs," said Mark Dreadin of Gulf Power's Pensacola District Engineering. Gulf Power recommended a package of energy saving measures that included GeoExchange systems as well as substantial thermal improvements as part of their Good Cents program.

"They are renovating from the ground floor on these units and bringing them up to Good Cents standards," said Richard Adams of Gulf Power's Pensacola District Marketing. "With the Federal government's interest in geothermal, this project is very important. It's going to serve as a hallmark for other areas of the country."

"A lot of people were involved and had a role in making it happen," said Adams. "We came in and showed the Navy what we felt was most energy efficient and they agreed with us."

Phased Construction

"We completed 14 housing units that will serve as our model, and will give us a guide, allow us to make changes and complete the remaining units," notes base Housing Director Ms. Rudy Weber. These Phase I living units at the Lighthouse Terrace complex have been occupied for about ten months (see Figure 1). The 12 units comprising Phase II of the project have been occupied for only a month. Renovation of 34 additional units is now underway on the third phase of the project. Eventually, all 236 living units at the Lighthouse Terrace complex will enjoy the energy and comfort benefits of GeoExchange combined with the Good Cents package of conservation measures.

Each phase was separately bid. The Phase 1 GeoExchange systems were installed by local Pensacola contractor Energy Systems Air Conditioning Company. Georgia Geothermal of Columbus, Georgia, was awarded the second and third phases.

WaterFurnace AT Premier Series GeoExchange units were installed in Phases I and II. However, the more basic Spectra Series has been selected for Phase III. For the first phase, two to three GeoExchange units are served by a single ground loop heat exchanger. However, each unit has its own separate ground loop in the second and third phases of the project.

Gulf Power is Monitoring Energy Savings

To verify estimated energy savings, Gulf Power is currently monitoring two of the four-unit buildings. One of the buildings has been totally renovated including installation of GeoExchange, thermal improvements, lighting retrofits, and new refrigerators. The other monitored building has not been retrofitted giving a good before and after picture of energy savings. Each unit in the unrenovated building has a furnace, water heater, and stove fueled by natural gas, and an electric air conditioner. The two buildings are in close proximity to each other and are similarly oriented to the sun.

Facility

- vertical wells, 200 to 225 feet deep
- each well serves about one ton of cooling load
- The 2-4-bedroom living units have cooling loads (after thermal improvements) of between 1½ and 2½ tons.

Location

The Lighthouse Terrace Housing is located in the Pensacola Naval Air Station, Florida.

Contact Information

Electric Utility

Gulf Power Company
500 Bayfront Parkway
Pensacola, FL 32520-0231
Keith Swilley, Marketing Manager, (904) 872-3202
Bob Magee, Military Segment Specialist, (850) 444-6013
David Shell, Residential Market Specialist, (850) 444-6021

Facility

Pensacola Naval Air Station
1581 Duncan Road

Pensacola, FL 32508
Ms. Rudy Weber, Housing Director, (850) 452-5289
Harry White, Public Affairs Officer, (850) 452-2311
Leo Deposito, Navy Public Works Center,
Project Manger, (850) 452-4774

Mechanical Contractors

Phase I:

Energy Systems Air Conditioning Company
1027 South Fairfield Drive
Pensacola, FL 32506
Tommy Marshall, President, (850) 456-5612

Phases II and III:

Georgia Geothermal
P.O. Box 4252
Columbus, GA 31904
Charles Davis, (800) 213-9508

GeoExchange Manufacturer

WaterFurnace International, Inc.
9000 Conservation Way
Fort Wayne, IN 48809
(219) 478-5667

1230 East 15th Street
Panama City, Florida 32402

Tel 904.872.3200

GULF POWER
A SOUTHERN COMPANY

February 10, 2000

Mr. John Carson
4104 NW 69th Street
Gainesville, Florida 32606

Dear Mr. Carson:

In response to your request during our recent telephone conversation, please find the enclosed information concerning the following geothermal projects:

- Pensacola Naval Air Station
- The Shores Condominium
- Koehnemann Construction

I hope this provides the information you need. In order to obtain additional information concerning the Building Life Cycle Cost, please contact Lawrence Clifton with the Pensacola NAS at (850) 452-4515 Ext. 352.

If you have any questions or if I can provide any additional assistance, please let me know.

Sincerely,

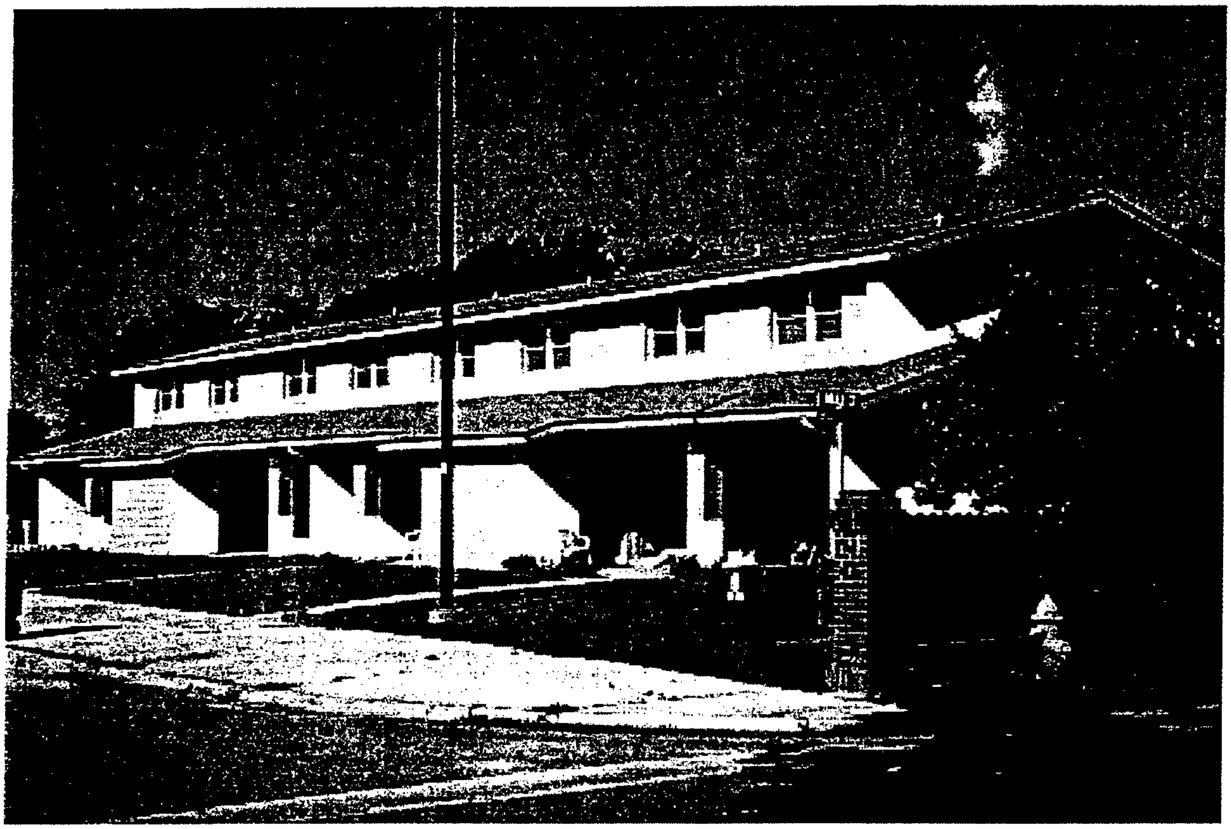
Keith Swilley

Keith Swilley
District Marketing Manager

KS:tlh

Enclosures

Lighthouse Terrace Renovation
Pensacola Naval Air Station
Pensacola, Florida



236 Units

Pensacola NAS Lighthouse Terrace Geothermal Conversion

Project Details

- Two-story townhouses
- Average 1,040 sq. ft. per dwelling
- 236 dwellings
- Whole-house renovation funded by Navy Housing

Before Renovation	After Renovation
Central Gas Furnace	Geothermal Heat Pump (closed-loop)
Central Air Conditioning	Electric Water Heating with Heat Recovery
Gas Water Heating	Electric Range
Gas Range	

Other Improvements

- Single-Paned to Doubled-Pane Vinyl Windows
- Metal Insulated Doors
- Increased Ceiling Insulation
- Additional Wall Insulation
- Ridge Vents
- Compact Fluorescent Lighting
- Low Flow Shower Heads

(* Thermal improvements allowed the geothermal units to be reduced by ½ ton per dwelling unit.)

Metered Data

Eight load research-type Electrical Meters collecting 15 minute interval data on:

Four renovated dwellings in one building
Four un-renovated dwellings in another building

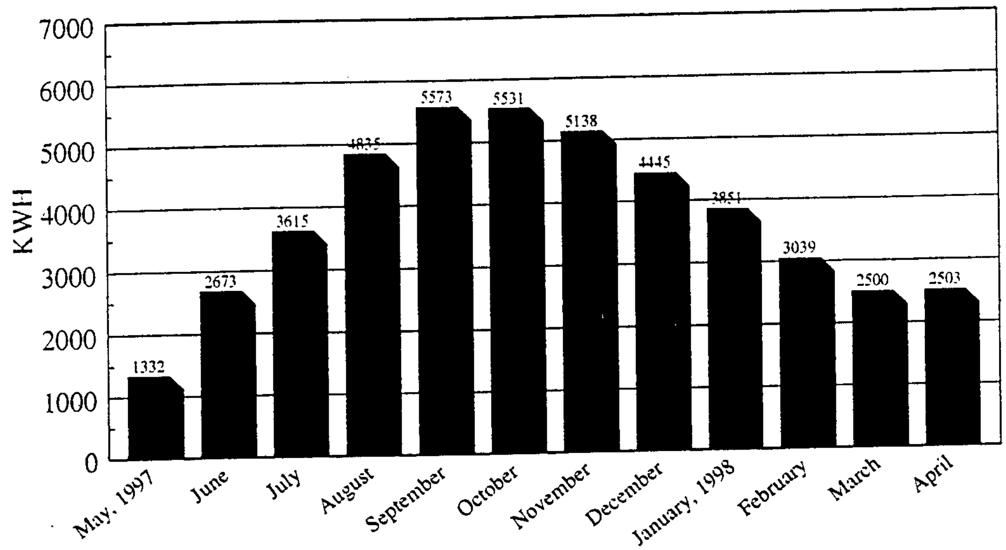
One new diaphragm-type Gas meter on the un-renovated building
Same size, similarly situated, close together.

Pensacola NAS Lighthouse Terrace Project
236 Units

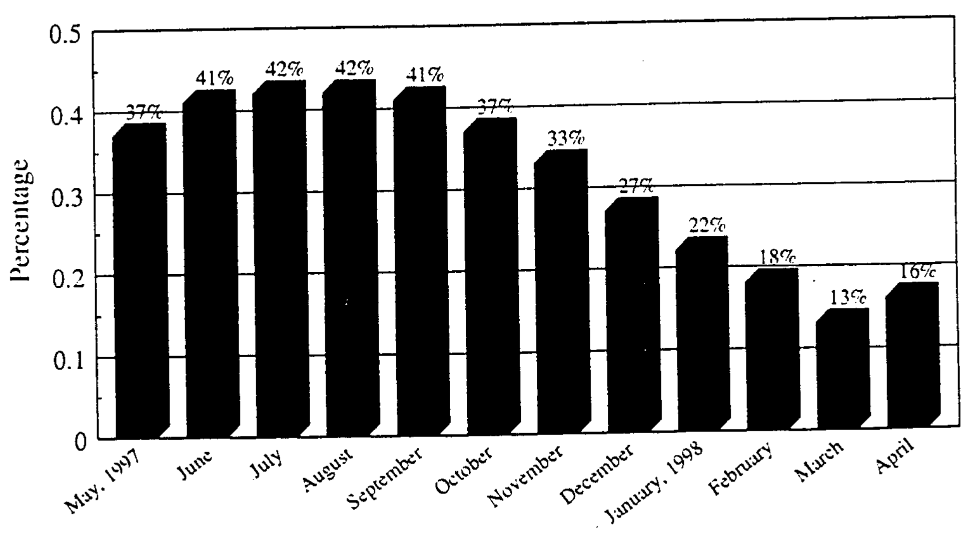
Summary of Energy Savings
(average per dwelling unit)

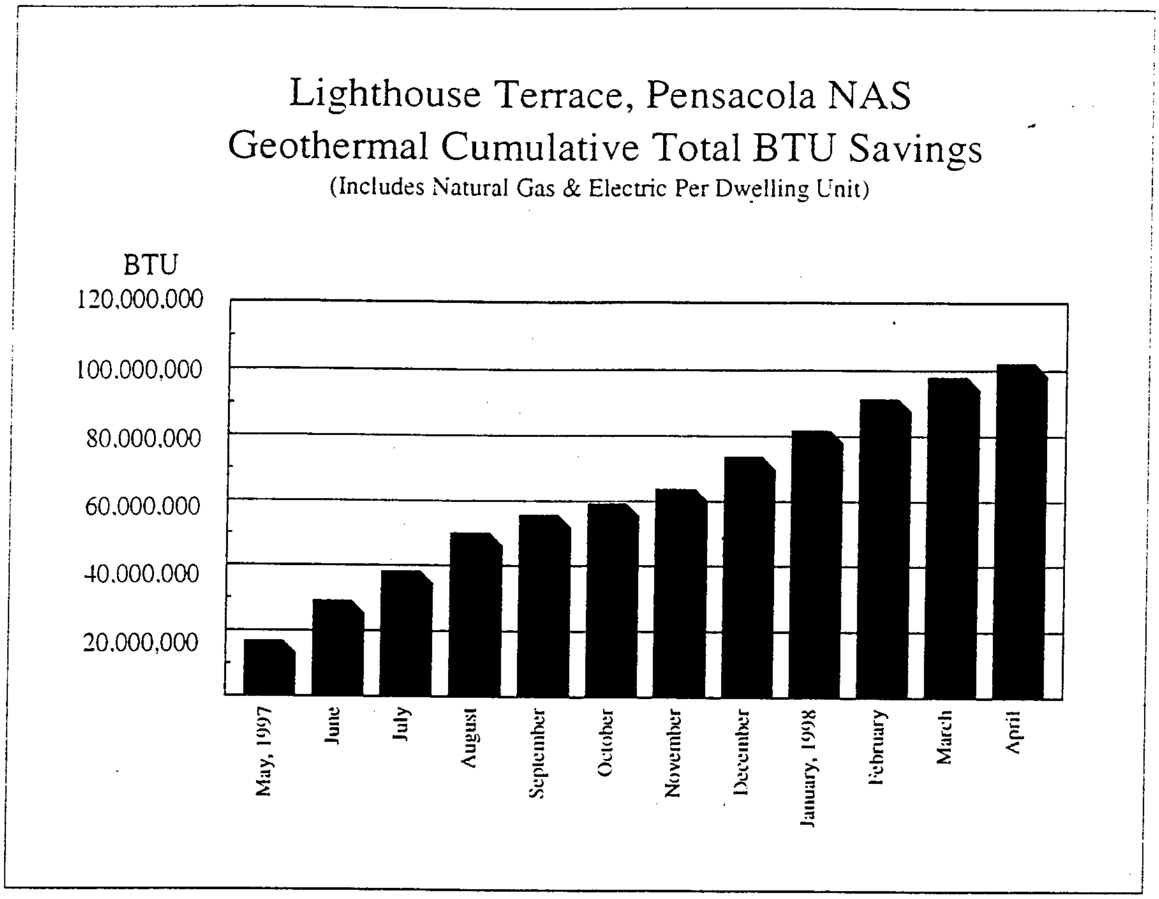
Average KWH Reduction:	2,503
Average KWH Percent Reduction:	16%
Natural Gas Reduction:	100%
Average Total Percent BTU Reduction:	63%
Average Dollar Savings:	$ 470
Summer Peak Reduction:	23%

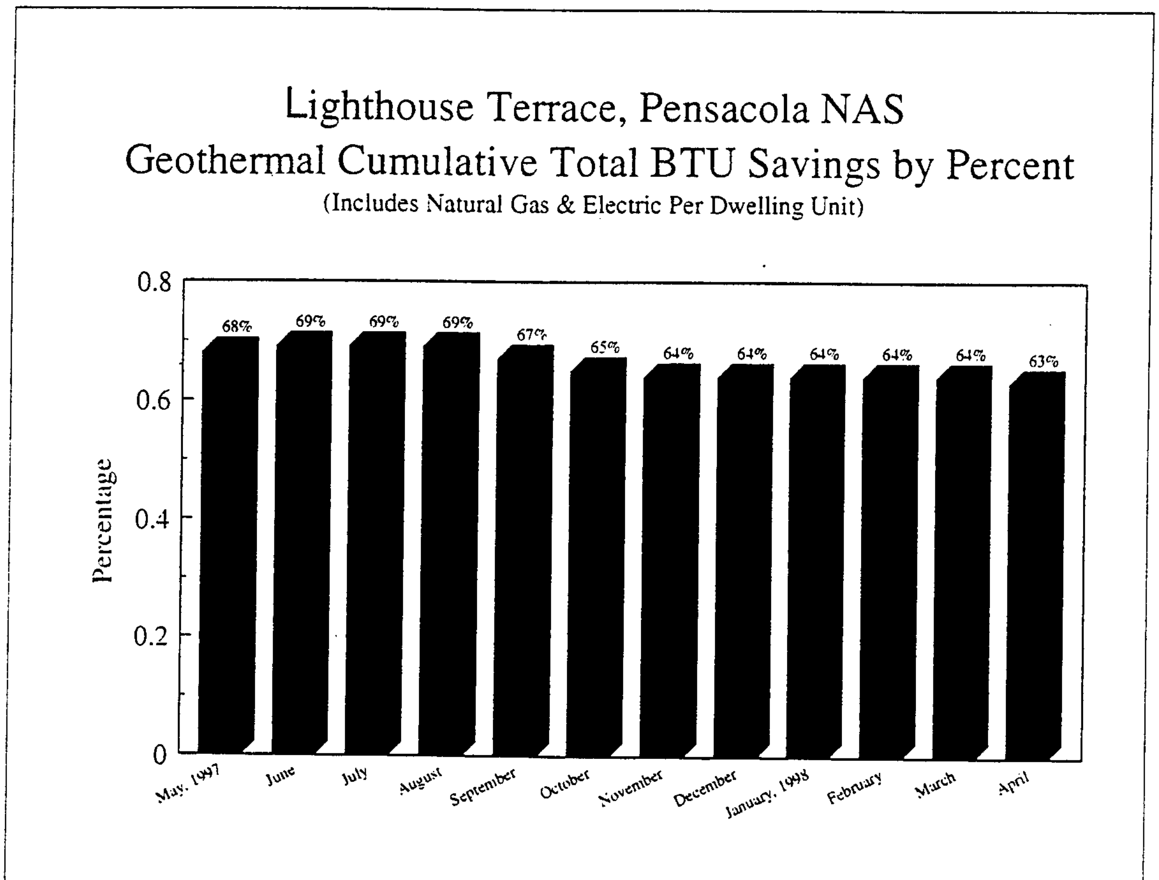
Lighthouse Terrace, Pensacola NAS
Geothermal Cumulative KWH Savings
(Per Dwelling Unit)

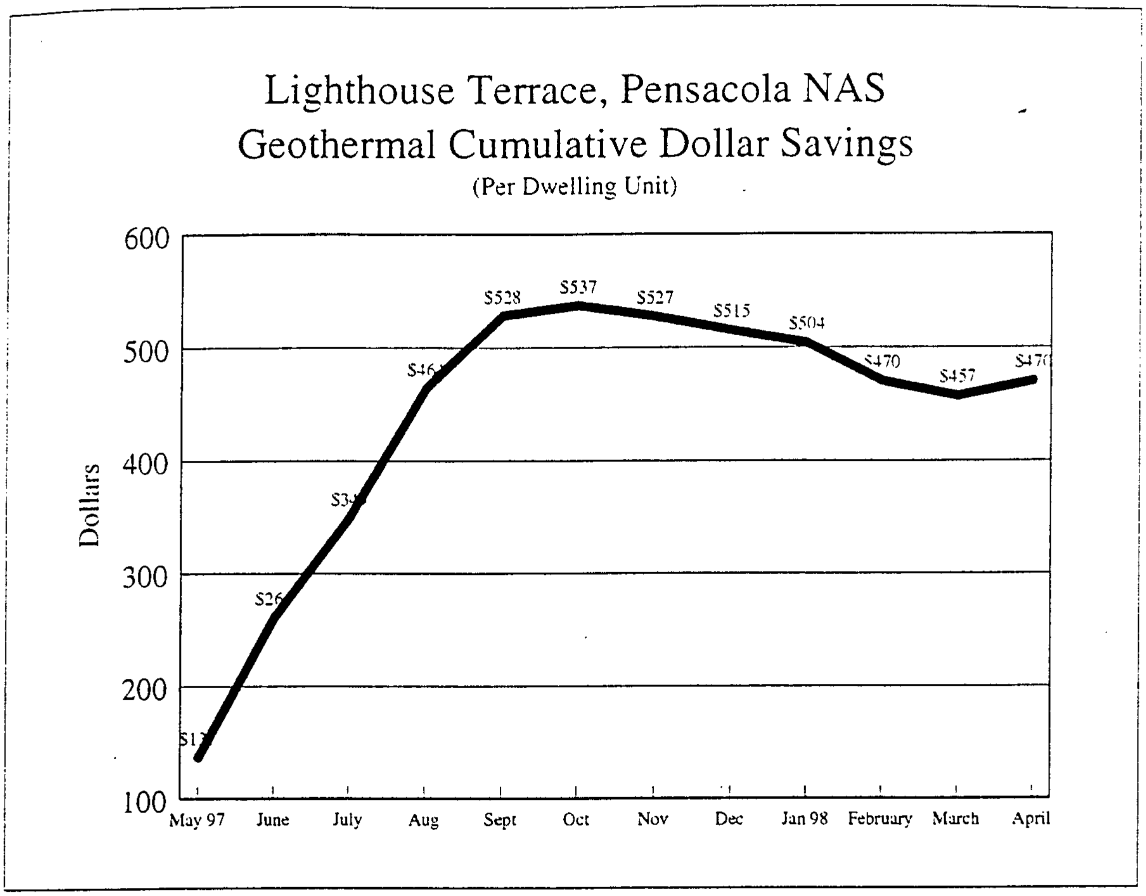


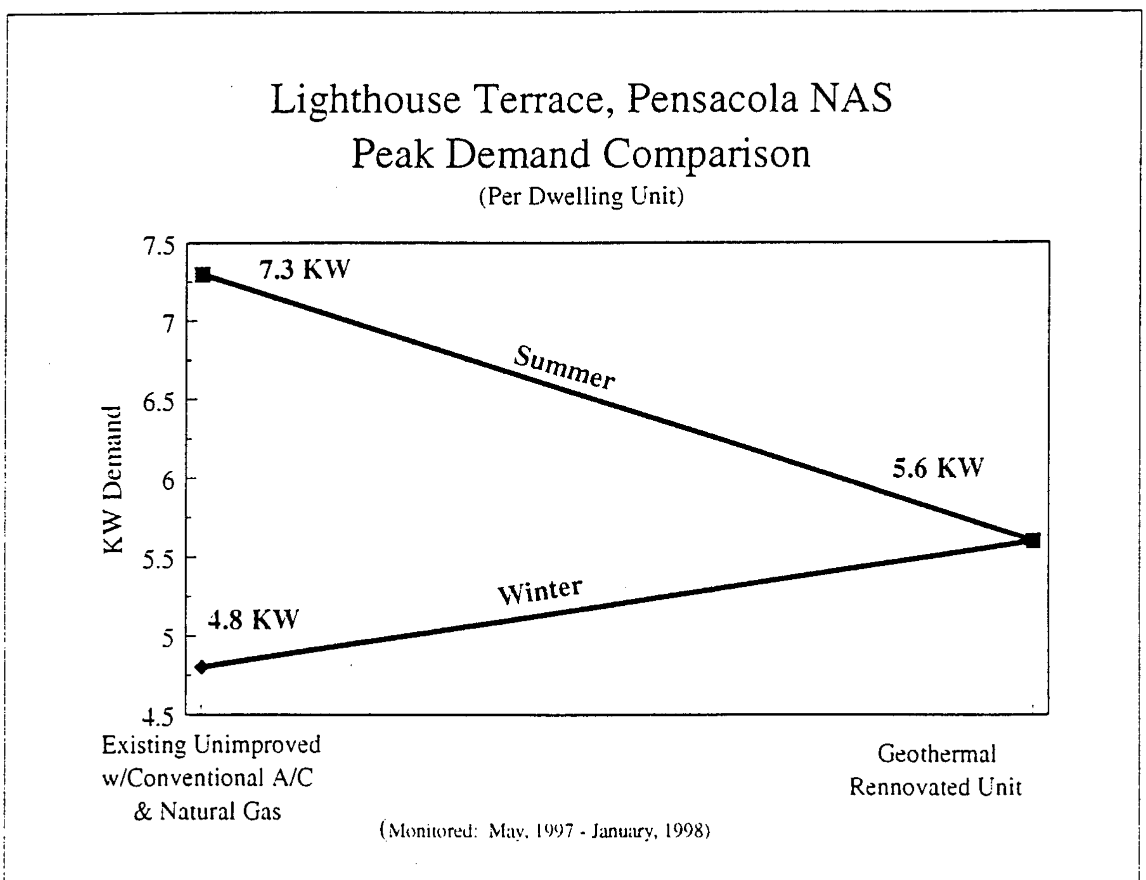
Lighthouse Terrace, Pensacola NAS
Geothermal Cumulative KWH Savings by Percent
(Per Dwelling Unit)




Lighthouse Terrace, Pensacola NAS
Geothermal Cumulative Total BTU Savings
(Includes Natural Gas & Electric Per Dwelling Unit)
BTU
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
May, 1997
June
July
August
September
October
November
December
January, 1998
February
March
April


Lighthouse Terrace, Pensacola NAS
Geothermal Cumulative Total BTU Savings by Percent
(Includes Natural Gas & Electric Per Dwelling Unit)
Percentage
0.8
0.6
0.4
0.2
0
68%
69%
69%
69%
67%
65%
64%
64%
64%
64%
64%
63%
May, 1997
June
July
August
September
October
November
December
January, 1998
February
March
April


Lighthouse Terrace, Pensacola NAS
Geothermal Cumulative Dollar Savings
(Per Dwelling Unit)
Dollars
600
500
400
300
200
100
$528
$537
$527
$515
$504
$470
$457
May 97
June
July
Aug
Sept
Oct
Nov
Dec
Jan 98
February
March
April


Lighthouse Terrace, Pensacola NAS
Peak Demand Comparison
(Per Dwelling Unit)
KW Demand
7.5
7
6.5
6
5.5
5
4.5
7.3 KW
Summer
5.6 KW
Winter
4.8 KW
Existing Unimproved
w/Conventional A/C
& Natural Gas
Geothermal
Rennovated Unit
(Monitored: May, 1997 - January, 1998)

The Shores Condominium
Panama City Beach, Florida

49 Residential Units

The Shores Condominium
Geothermal Retrofit

Pre-Existing Equipment	Retrofit Equipment
Conventional Air Conditioners	Trane Geothermal Split Systems
Central Electric Furnace	Factory Built-in Heat Recovery
Electric Water Heating	Electric Water Heating

Other Project Notes

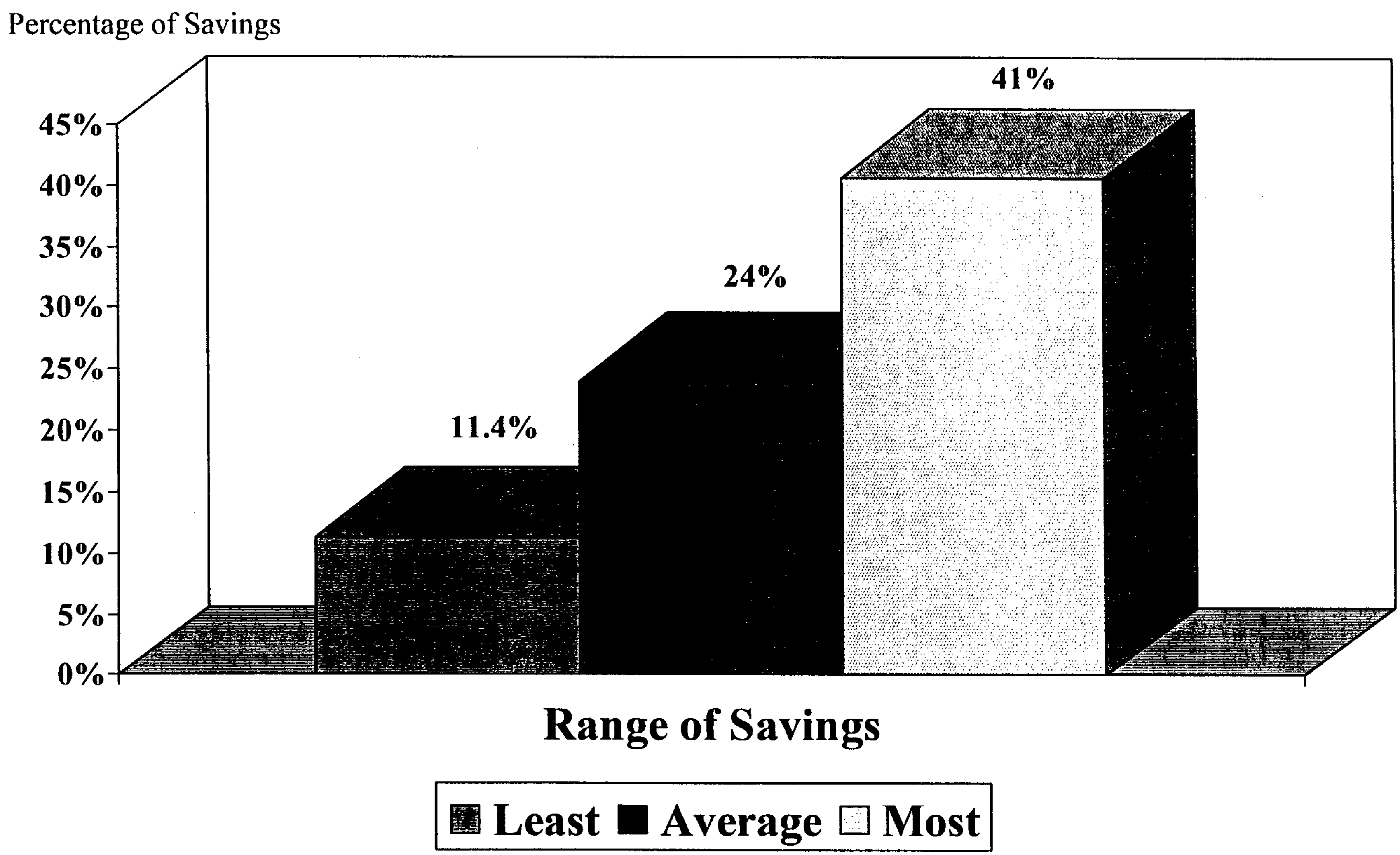
- Located directly on the Gulf of Mexico
- Project resulted from damage of Hurricane Opal
- One common (diversified) loop which reduced 5,000 bore feet
- 151 total tons
- Circulating pump energy paid by Homeowners Association
- Stand-by back-up pump
- Split systems were installed due to limited space in the air handler closet
- Average installed cost per ton - $2,500

Geothermal Benefits that "Sold" Owners

- Efficiency – Energy Savings
- Long Equipment Life
- Low Maintenance
- No Outdoor Equipment

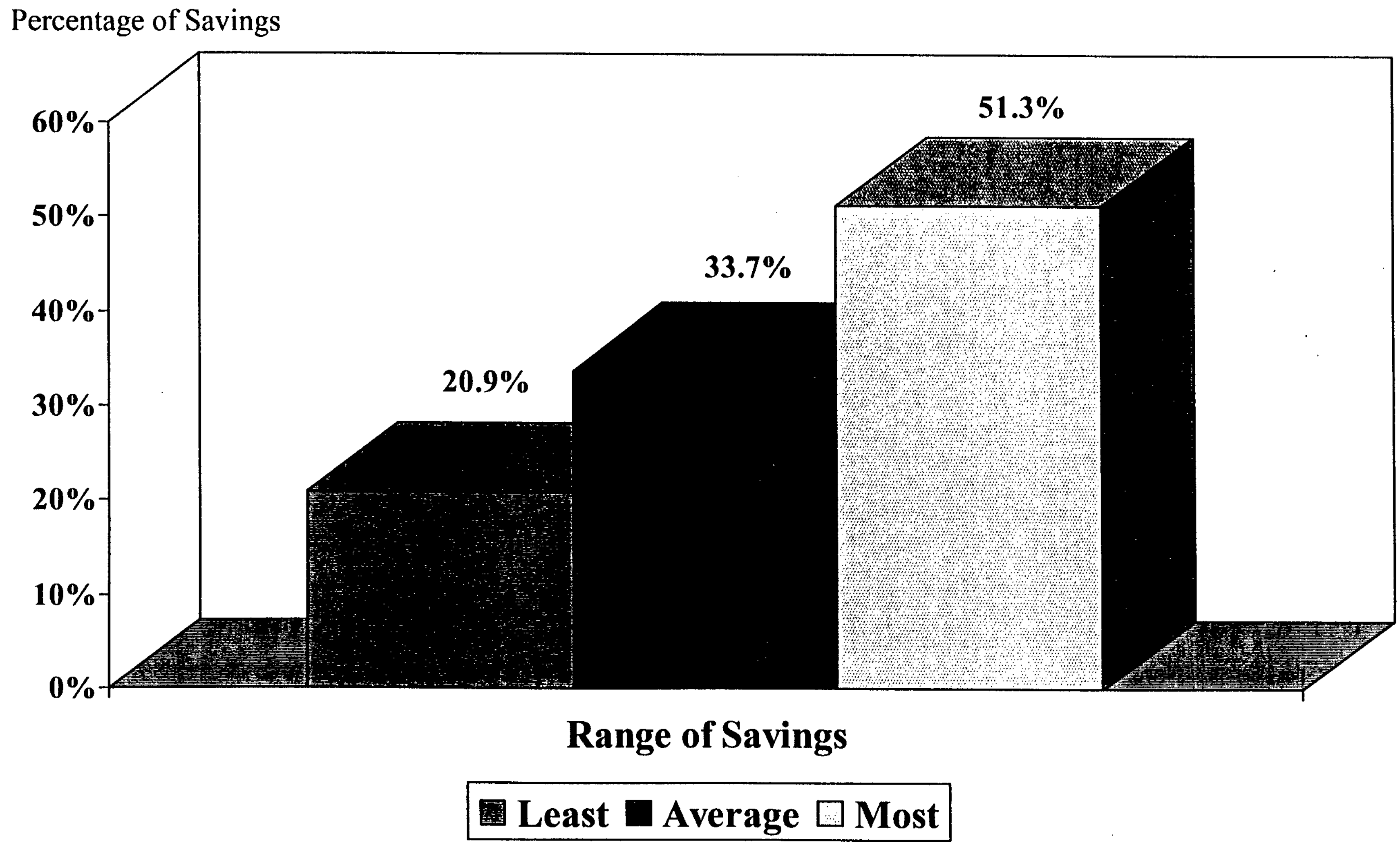
Note: Testimony from this project was used in Gulf Power's geothermal video.

The Shores Condominium
Geothermal Energy Savings
(Full-time Residence Units)



shoresres.ppt

The Shores Condominium
Geothermal Energy Savings
(Rental Units)



shoresres.ppt

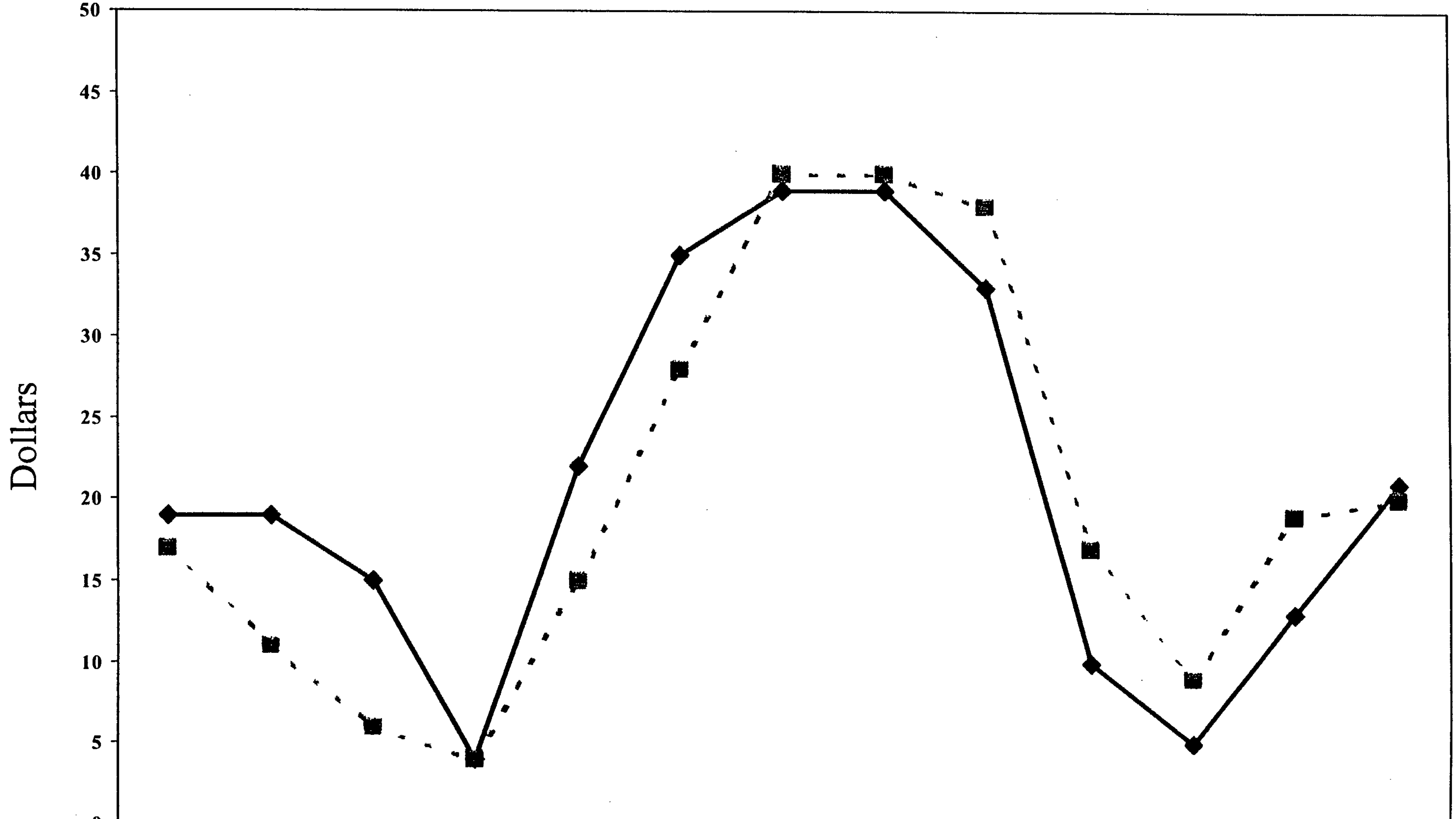
Koehnemann Construction
Panama City, Florida

2,000 sq. ft. Good Cents All-Electric Home
Closed-Loop Geothermal System
Waterfurnace AT028 with built-in Hot Water Recovery

65-gallon Electric Water Heater (Set point 120 degrees)
R-38 Ceiling, R-19 Walls, Double-pane Windows
House Heat Gain = 21,000   Heat Loss = 25,000

Geothermal Heating & Cooling Operating Costs

Koehnemann Construction - 2,000 sq. ft. Home



	January	February	March	April	May	June	July	August	September	October	November	December	Avg Mthly Bill
1996	19	19	15	4	22	35	39	39	33	10	5	13	21
1997	17	11	6	4	15	28	40	40	38	17	9	19	20

koeh.ppt

Case Study

Patuxent River Naval Air Station, Maryland

Courtesy Pepco Services Inc.

An early success story in military applications of GeoExchange

- Project
- Facility
- Contact Information

Project

Frank Knox Office Building

Background

As far back as the late 1980's, the base energy manager at Patuxent River began exploring the economic benefits of GeoExchange. But at the same time, there was not widely understood in the US, and installation costs were higher than most conventional systems, even though operating costs were lower. The local area also seemed to lack the support system to fully embrace the technology. Base engineering naturally questioned the lack of local parts, reliable contractors, and maintenance specialists in GeoExchange.

Soon, however, the case for this technology was heightened when several local businesses and residents discovered its benefits. A sports complex in a nearby town was retrofitted with a GeoExchange system, and a number of local home owners began to install this technology. Plans also were in the works for two motels and a church in town.

With growing support from the naval air station command, the energy manager at the time, Mel Green, persisted in his quest to bring GeoExchange to the base. He contacted leading heat pump manufacturers who helped the station find local contractors to bid on GeoExchange projects. And he pushed for GeoExchange systems to be included in life-cycle cost analyses for alternative space-conditioning systems. Green has won two Federal Energy-Efficient Awards and a Meritorious Service Medal for other Patuxent energy projects.

How to Promote GeoExchange

according to Mel Green, Energy Manager at Patuxent River from 1987 to 1994

Gather and disseminate information on GeoExchange.

Enlist the help of key officials.

Recommend GeoExchange whenever possible.

Anticipate procurement snags; revise forms to handle GeoExchange.

PERSISTENCE, PERSISTENCE, PERSISTENCE is the key.

The Projects

At the Patuxent River Naval Air Station, GeoExchange systems are saving energy dollars at two on-base office facilities. The GeoExchange projects came about, in part, because base engineers and management came to believe that the systems could save energy dollars. When Building 114, a three-story, 8,270 square foot building came due for refurbishing, a GeoExchange system was installed. The project was financed with Base Repair Funds. By late 1993, Patuxent's first GeoExchange system was up and running.

By this time, Naval Engineering Facilities Command guidelines had been revised to include GeoExchange systems. The number of contractors and energy specialists working with this technology in the region had also dramatically increased. The local utility co-hosted a symposium on the base which drew over 25 local contractors and featured GeoExchange expert Dr. Jim Bose of Oklahoma State University. GeoExchange certification classes to local installers followed.

When the Frank Knox School, one of the older facilities on the base, became due for renovation and conversion to office space, engineering managers spotted another opportunity for GeoExchange. After evaluating a number of heating and cooling technologies, base command approved a geothermal retrofit, and the facility now enjoys increased comfort along with cost savings.

Facility

BUILDING 114

8,270 square foot, 3-story cinderblock building
Number of heat pumps: 3
Size of heat pump: 3 to 5 tons each
Heat pump manufacturer: Climate Master

FRANK KNOX SCHOOL

38,410 square foot, single story building
Number of heat pumps: 18
Size of heat pump: 5-20 tons each
Heat pump manufacturer: Climate Master

Contact Information

Key Players

Naval Facilities Engineering Service Center - Suresh Garg, 805-982-1325; sgarg@ncel.navy.mil

U.S. Army Cold Regions Research and Engineering Laboratory - Gary Phetteplace, 603-646-4248; gephet@crrel.usace.army.mil

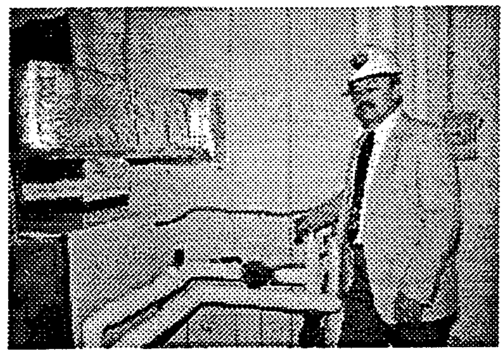
Utility - Southern Maryland Electric Cooperative Mike Rubala, 301-475-5631, Ext. 1-4338

Ground-Loop Installer - Buddy Winslow, Winslow Pump and Well, 800-882-0200

Patuxent Energy Manager - Mel Green, 301-342-3101 Ext. 389, Green_MelPAX9A@mr.nawcad.navy.mil

Persistence, Persistence, Persistence: Championing Geothermal Heat Pumps at Naval Facilities

By Deborah S. Page and Lisa C. Dawkins



Retired Naval Aviator Mel Green is one of the leading proponents of GHP technology. When Green became Energy Manager of Public Works at the Patuxent River Naval Air Training Center/Naval Air Station (NATC/NAS) in January 1987, he began asking questions about energy consumption and the heating/cooling systems used on the base. His interest in GHPs eventually led to changes in the base energy program and an important demonstration of GHP technology in a military setting.

Mel Green has always been interested in the economics of saving energy. When he was made Energy Manager of the NATC/NAS, he saw an opportunity to put that interest to work by exploring ways to reduce energy consumption at the base. After taking classes in energy management, he evaluated a number of space conditioning systems and found that geothermal heat pumps showed substantial energy savings compared with the other systems evaluated. Mel began sharing this information with the base Engineering Department.

Mel saw his first opportunity to install GHPs in May 1989. Base housing was replacing some #2 fuel oil heating systems with air-to-air heat pump systems. Of the 600 units due for replacement, 200 had already been replaced. When Mel urged Engineering and the Base Housing Director to consider using GHPs for the remaining 400 houses, he met some strenuous objections. The Base Housing Director was concerned about the high installation cost of GHPs (even higher then than now because the technology was so new), as well as disruptive installation drilling and the noise of heat pump compressor. At that time, Mel didn't have enough evidence to convince her that GHPs were no more noisy than a household refrigerator. Engineering staff also questioned the adequacy of the GHP infrastructure, citing concerns about the local area's lack of reliable contractors, availability of parts, and future maintenance.

Formidable government paperwork requirements constituted another roadblock. The Naval Engineering Facilities Command's (NAVFAC's) guide specifications were not flexible enough to include a new technology such as ground source heat pumps. Engineering staff were reluctant to write guide specifications for a technology with which they were unfamiliar, understandably concerned that the result would be procurement of poor quality equipment. Another procurement issue was the military's financial treatment of new projects versus repairs/renovations to existing facilities. New projects over $300,000 require Congressional approval, which can take up to five years. Since GHPs' installation costs were so high, a "new" project was difficult to complete for

under $300,000. Consequently, Mel was unable to muster support for several GHP projects.

Mel retired in June 1989 and returned as a civilian to the same job late in the same year. He renewed his GHP campaign with increased vigor after going to Oklahoma State University in early Spring 1990, where he met Dr. Jim Bose, a GHP advocate for many years. Dr. Bose was largely responsible for the installation of about 600 tons of GHP technology at the state capitol building in Oklahoma, a state with abundant natural gas. The insights Bose provided from his own experience with successful GHP operations convinced Mel that many of the objections to GHPs he had encountered were unfounded.

Mel shared what he learned with key decision makers at the base, such as engineering personnel and his business manager (who was soon convinced of the economic advantages of GHPs). An opportunity to install a GHP system arose when Building 114, a 6200 square foot windowless, three-story cinder block building, was due for renovation. When Mel again approached the engineering department with proposals for a GHP system, they were persuaded that a GHP system was worth a try. Because this project was considered a renovation, procurement paperwork was not an obstacle. A closed loop geothermal heat pump installation was approved. By this time, NAVFAC specifications had been revised to include GHPs. The base engineers had taken training classes on GHPs at Oklahoma State University and had written the particular guide specification for Building 114. The specifications established an Energy Efficiency Ratio (EER) rating of 12 for the GHP. They also included the evaluation of scroll compressors, top-of-the-line compressors that are compatible with GHP systems. The general parameters used were 400 feet of pipe per ton of space conditioning. Space considerations dictated a vertical pipe configuration.

The system was designed and ready for installation, and then funds ran dry. The project was temporarily shelved. Base Realignment and Closure (BRAC) funds eventually became available, providing an opportunity for the GHP installation. By this time, there were at least twelve ground loop installers in the area and GHP contractors were not hard to find. Mel contacted marketing specialists from a number of major GHP manufacturers, such as Climate Master, Water Furnace and Trane, who came to the are and helped find contractors to bid on the project. In addition, Southern Maryland Electric Cooperative (SMECO), the local utility, was giving GHP certification classes to local installers.

Two 5-ton and one 3-ton Climate Master GHP systems were installed in Building 114 in late 1993. The GHPs are now operating and the overall renovation is complete.

Mel Green soon found another opportunity for a GHP conversion on the base. An old building on the base, the Frank Knox School, was also due for renovation and conversion to office space under BRAC funding. When comparative life cycle cost analyses were being prepared for alternative heating and cooling systems, Mel urged the inclusion of GHPs in the comparisons. Although GHPs compared unfavorably in the initial analysis, Mel discovered errors in the analysis relating to natural gas prices, electric utility demand fees, and failure to include utility rebates for GHP and other alternative systems that help shave utility peak loads. With the application of a $65,000 rebate, the 25-year life cycle cost for GHPs was the lowest of the systems considered. A GHP retrofit of the Frank Knox School was approved. The 1940's style brick school building now uses a GHP system, with a closed loop vertical heat exchanger to provide both heat and air conditioning. Energy performance monitoring will be carried out by the

Naval Facilities Engineering Service Center (NFESC) and the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL).

Interest in GHPs in the civilian community around NATC/NAS also helped build the case for their use at the base. Several years ago, a sports complex in the nearby town was retrofitted with closed loop ground-coupled heat pump. In addition, homeowners throughout the community began using GHPs and plans are now underway to install GHPs in two motels and a church in town. Not surprisingly, the number of contractors and energy specialists working with GHPs in southern Maryland has increased dramatically. When SMECO asked Mel to help organize a GHP symposium in 1990, over 30 contractors and GHP specialists attended.

Mel offers the following suggestions out of his own experience for promoting GHPs in a DOD environment: 1) Gather and disseminate all written material you can find on GHPs. Enlist the help of key officials. When both Mel's Business Manager and Commanding Officer became committed to a GHP program, things started moving more quickly; 2) Continue suggesting GHPs whenever the opportunity arises; 3) Anticipate possible procurement paperwork snags, making sure that forms are written to handle GHP specifications. (Examples of these are Project Data Sheets, the first step in making budget proposals, and 1391's, forms used for military projects exceeding $300,000.)

Mel says that he was lucky to recognize early the importance of GHPs and loud enough to persist in campaigning for their use. He feels that his progress has always been a team effort, with support from both the private and military sectors. And, he says, it certainly helps to start with a significant technology worth recognition. As Mel Green's experience has demonstrated, lots of PERSISTENCE, PERSISTENCE, and PERSISTENCE is the key ingredient in ensuring more widespread use of this clean, efficient, and economical technology.

SERDP: EFFICIENCY AND ECOLOGY

The Strategic Environmental Research and Development Program (SERDP) is a Congressionally mandated program that is putting millions of dollars into fast-tracking environmental technologies in the defense sector. Six specific "Thrust Areas" have been targeted by this initiative, including the Energy Conservation/Renewable Energy Thrust Area. One facet of this area is promoting the expanded and accelerated use of GHPs at DOD facilities. Since the defense sector is the single largest user of electricity in the United States, widespread use of GHPs at DOD facilities can significantly reduce energy use, maintenance costs and emissions. Demonstration projects are being developed at eight DOD sites nationwide, including the Patuxent River NAS project. A demonstration at Ft. Polk, Louisiana, where over 4000 GHP units are being installed and monitored, is receiving a great deal of attention.

Mel Green's changes at Patuxent River NAS were so effective that he has been given two Federal Energy Efficiency Awards and a Meritorious Service Medal.

Marine Corps Air Station, New River, North Carolina

- Project
- Facility
- Location
- Contact Information

Project

Single enlisted personnel at the Marine Corps Air Station in New River, North Carolina, will soon enjoy the comfort of GeoExchange technology, but base housing officials and the U.S. Department of Defense will also smile at the energy savings. Two enlisted-person barracks buildings are currently under construction at the air station located across the New River from the Camp Lejeune Marine Corps Base. GeoExchange systems will provide space heating, space cooling, water heating, and will reduce the energy penalties usually associated with bringing in fresh outdoor air for ventilation.

The Bachelor Enlisted Quarters (BEQ) project at New River Marine Corps Air Station is constructing two three-story buildings each with a gross floor area (including stairs and exterior walkways) of 68,610 square feet, for a total of 137,220 square feet. Each building will contain 52 living modules measuring 750 square feet each, which consist of two bedrooms and share a bathroom, kitchenette, and closets. There will be 1,980 square feet of laundry and janitor rooms, and a 1,740-square-foot multi-purpose room. Electrical and mechanical spaces total 9,145 square feet.

Ellen Freihofer, manager of the GeoExchange project for the Atlantic Division Naval Facilities Engineering Commend (LANTDIV) in Norfolk, Virginia, says that LANTDIV had used a GeoExchange system in an office building in Norfolk and was pleased with its performance. Since the proposed new enlisted quarters was to be located quite a distance from existing steam lines, LANTDIV asked the design engineering firm to conduct an analysis comparing the life-cycle cost of extending the steam lines to heat the building with steam equipment to the cost of GeoExchange system. With its low operating costs, the GeoExchange system was the clear winner.

The GeoExchange System

Each living module will be heated and cooled by a GeoExchange unit manufactured by

WaterFurnace International. The SX Spectra Series units range in size from ¾ to 1½ tons of refrigeration depending on living module location and exterior orientation.

Incorporated into each GeoExchange system is a "desuperheater" -- a refrigerant-to-water heat exchanger that captures excess thermal energy from refrigerant to heat domestic water. The desuperheater feeds a water coil in the electric water heater located in the common area of each living module. In the summer, the heat removed from the living space will supply all the living module hot water needs at the Bachelor Enlisted Quarters. The standard electric coils in the water heater supplement the desuperheater during peak winter conditions.

Each building has two make-up air units to ensure indoor air quality by bringing in fresh, outdoor air. The . The make-up air units recover heat from the bathroom room exhaust air via a plate-type heat exchanger and use it to temper the outside ventilation air.

The GeoExchange units in each building are served by a ground heat exchanger. Each building has a separate loop. Each loop consists of eight circuits of eight wells each totalling 64 wells per building each 4 inches in diameter and 234 feet deep. Each circuit employs a reverse return configuration that equalizes heat rejection characteristics of each individual well. Each circuit begins and ends with shut-off valves located inside an underground, concrete distribution pit.

The ground loop consists of 1-inch-diameter, high-density polyethylene pipe made by Phillips Driscopipe installed in the boreholes. Two-inch pipe runs from the wells to the valve center, and 3-inch pipe carries the heat exchange fluid to the building. Wilaon, P.E., WaterFurnace, the mechanical contractor (Ramsey Air Conditioning), and Carolina Power & Light. ***GCHPCalc***, software developed by Dr. Steve Kavanaugh of the University of Alabama, was used to size the ground loops. The loop design was tuned based on a thermal conductivity analysis of a grouted test well conducted by Ewbank & Associates for by Carolina Power & Light Company.

A 10-hp pump circulates an environmentally friendly freeze-protection solution through the ground loop. Pump operation alternates between the primary and its stand-by every other week to equalize wear and tear.

The GeoExchange system was designed by Elizabeth Kotek, a professional engineer with the architectural, engineering, and planning firm of ENG/6A of Asheville, NC, in consultation with WaterFurnace, the mechanical contractor (Ramsey Air Conditioning), and Carolina Power & Light. ***GCHPCalc***, software developed by Dr. Steve Kavanaugh of the University of Alabama, was used to help size the ground loops. The loop design was fine tuned based on a thermal conductivity analysis of a grouted test well that was paid for by Carolina Power & Light Company.

The drilling contractor is Climate Control Heating and Cooling Company of Jacksonville, North Carolina. President Mike Hadley says that Climate Control added GeoExchange systems to their capabilities about three years ago after being approached by Tom Trantham, Senior Territory Manager at WaterFurnace International and manufacturer's representative for the New River Marine Corps Air Station project. Climate Control has installed about 50 ground loops. They have received WaterFurnace training and are certified by the International Ground Source Heat Pump Association is qualified ground loop installers. Mr. Hadley is also bringing in Georgia Geothermal of Columbus, Georgia, to help expedite the well drilling.

Summary

The Marine Corps Air Station at New River is just one of a growing number of military facilities enjoying the benefits of GeoExchange technology. Other bases with GeoExchange include: Fort Polk, LA; Fort Hood, TX; Fort Riley, KS; Quantico Marine Base, VA; Dyess Air Force Base, TX; Bolling Air Force Base, VA; Hill Air Force Base, UT; Selfridge Air National Guard Base, MI; Naval Security Group Northwest, VA; and Patuxent River Naval Air Station, MD. Will your facility be next?

Facility

- vertical closed-loop
- 2 units rated at 15 and 10 tons, served by a water-to-water heat pumps
- each building has a separate loop, each loop consists of eight circuits of eight wells each totalling 64 wells per building each 4 inches in diameter and 234 feet deep.
- the ground loop consists of 1-inch-diameter, high-density polyethylene pipe

Location

The Marine Corps Air Station is located in New River, North Carolina.

Contact Information

Navy Contacts:

Atlantic Division Naval Facilities Engineering Command (LANTDIV)
1510 Gilbert Street
Norfolk, VA 23511
Ellen Freihofer, Project Manager (757) 322-8346
Brian Cooper, Mechanical Engineer (757) 322-4242

New River Marine Corps Air Station
PSC Box 21001
Building AS-211
Jacksonville, NC 28545-5001
Tricia Hiers, Mechanical Engineering Technician, Station Facility Planning, (910) 451-6506

Utility Representatives:

Carolina Power and Light Co.

1099 Gum Branch Road
Jacksonville, NC 28540
Greg Leach, Energy Svcs Engineer (919) 481-6115
Don Hamilton, Energy Svcs Engineer (910) 346-1416

GeoExchange Manufacturer:

Tom Trantham, Senior Territory Manager
WaterFurnace Int'l, Inc.
1343 Brawley School Road
Mooresville, NC 28115
Phone: (704) 662-7762

WaterFurnace Corporate
9000 Conservation Way
Fort Wayne, IN 48809

Mechanical Engineer:

Elizabeth G. Kotek, P.E.
ENG/6A
1095 Hendersonville Road
Asheville, NC 28803-1801
Phone: (704) 274-1551
Fax: (704) 274-8458

Mechanical Contractor:

Kurney Ramsey
Ramsey Air Conditioning
Phone: (910) 455- 0414

Drilling Contractors:

Mike Hadley, President
Climate Control Heating and Cooling Company, Inc.
269 Center Street
Jacksonville, NC 28546
Phone: (910) 353-9040

Charles Davis
Georgia Geothermal
P.O. Box 4252
Columbus, GA 31904
Phone: (800) 213-9508

GeoExchange Distributor:

Hoffman and Hoffman
6120 St. Giles Street

Raleigh, NC 27612
Bill Poole, Sales Engineer
Phone: (919) 781-8011

TO: LT. JOHN CARSON

FROM: Glenn White - 850-623-7181 x 44
NAS Whiting Field.

Find attached the scope of work and Life Cycle cost ANALYSIS.

SUPPLEMENT 1 TO EXHIBIT "C"

Exhibit C (the "Authorization") to General Services Administration AreaWide Utilities Contract Number GS-OOP-96-BSD-0022 for Electric And Steam Services (the "AreaWide Contract") between the Department of the Navy (Government) and Gulf Power Company (Contractor) is supplemented as follows.

1.0 PURPOSE AND SCOPE

The Whiting Pines military family housing area near NAS Whiting Field contains 229 single-family Capehart and 100 duplex Fund dwelling units. All 329 housing units are presently equipped with split system air conditioners, gas furnaces, gas cook stoves, and gas domestic water heaters. The purpose of this project is to replace the existing HVAC equipment with ultra high efficiency geothermal heat pumps for space heating and cooling, install larger capacity electric water heaters served by desuperheaters from the heat pumps for domestic hot water production, and install electric stand-alone cook stoves. Contractor shall make all arrangements necessary to deliver the prescribed services.

2.0 TASK DESCRIPTIONS

There are four (4) separate tasks comprising this project, some of which require careful scheduling for proper work flow. Each of the tasks is described in the following paragraphs.

2.1 Task 1 - Install Geothermal Ground Loops

A separate, dedicated vertical geothermal ground loop system shall be installed in the back yard of each of the 229 Capehart housing units. Two dedicated vertical geothermal ground loop systems shall be installed in the back yard of each of the 50 Fund duplex housing buildings, one to serve each of the two residential units contained in the building. Loops shall be designed to meet heat rejection and retrieval requirements for the geothermal heat pump equipment installed in the housing units. Loops shall be installed in accordance with specifications developed by the International Ground Source Heat Pump Association. Individual loops shall be headered-up underground external to the housing unit. One supply and one return line shall enter each housing unit, and be connected to a circulation pump mounted in the mechanical room adjacent to the geothermal heat pump unit. Trace tape shall be buried above each loop and interconnecting pipe.

All disturbed grass areas shall be returned to existing condition. A number of the housing units have owner-installed fencing around the back yard. A section of the fence may need to be removed by the loop installer to allow access for drilling equipment. Any disturbed fence shall be restored to existing condition when the ground loop installation has been completed.

2.2 Task 2 - Demolish Existing HVAC Equipment and Install Geothermal Heat Pump Equipment

Existing outside air conditioning compressor/condensing unit, disconnect box and wiring, refrigerant line set, thermostat, and the gas furnace/AHU in the mechanical room shall be demolished. Mercury switches shall be removed from the thermostat and turned over to Government for disposal. All other demolished equipment shall be removed from government property and properly disposed of by installing contractor. CFC refrigerant in the compressor shall be captured by a licensed technician and shall become the property of installing contractor. Any mounting holes in the rear wall of the building where the disconnect box was removed shall be filled and the area spot painted to match the building color.

A geothermal heat pump (GHP), with integral desuperheater, and a loop circulating pump of appropriate size shall be installed in the mechanical room. The GHP unit shall be mounted on a sound deadening pad, and adapted to existing ductwork. Existing electric connections shall be used to power the GHP unit. The ground loop shall be purged and the loop supply and return lines connected to the loop circulating pump and GHP using the manufacturer's standard hookup kit. Any wall penetrations shall be neatly made and sealed for a finished appearance. Existing condensate drain line shall be connected to the GHP. An appropriate GHP thermostat shall be installed at the location of the original thermostat and connected to the GHP. The GHP shall be started and tested for leaks and proper operation.

2.3 Task 3 - Demolish Existing Water Heater and Install New Water Heater

The existing gas domestic water heater shall be drained, demolished, and removed from Government property. Existing water heater vent pipes shall be capped, as necessary. A new electric water heater shall be installed in place of the old unit and plumbed to existing inlet/outlet pipes in the housing unit. No galvanized piping, nipples, unions, or other devices may by used. A dedicated electric circuit of appropriate capacity shall be installed to serve the new electric water heater. The new water heater shall be plumbed, using the manufacturer's standard hookup kit, to the integral desuperheater in the GHP for production of domestic hot water.

2.4 Task 4 - Remove Existing Gas Cook Stoves and Install New Electric Cook Stoves

Existing gas cook stoves shall be demolished and removed from Government property. Existing gas piping shall be capped, as appropriate. New electric cook stoves shall be installed in place of the old gas units and necessary wiring will be installed to power the unit.

3. ACCESS TO PREMISES

Because the housing units to be fitted with new GHP/water heating equipment are occupied, all work in and around the individual housing units must be done in close coordination with the residents through the Housing Office. Installing subcontractor shall notify each resident by posting a notice at the housing unit a minimum of five working days in advance of the anticipated work day to allow occupants time to remove all personal items from the area where work will be done.

All work on the interior of any given housing unit shall be accomplished in a single day, between the hours of 0730 and 1600. In no circumstance shall any housing unit be left without heating/cooling and hot water over night.

The installing contractor shall contact NAS Whiting Field contract inspector to coordinate all on site work, including personnel and vehicle access. Any required burning permits, digging permits, and property passes shall be obtained from NAS Whiting Field.

4. DISPOSAL OF REMOVED MATERIALS

Contractor shall take possession of all removed materials and equipment, with the exception of the mercury switches from the thermostats. Removal from government property and proper disposal of discarded materials and equipment shall be the responsibility of the installing contractor.

5. HAZARDOUS MATERIALS

It is not anticipated that any asbestos containing materials (ACM) will be encountered during implementation of this project. If Contractor personnel encounter any suspected ACM, work on that part of the project shall cease immediately and the CES shall be contacted. Government shall be responsible for mitigating any ACM situation, and Contractor shall not resume work on that part of the site until so directed by the Contracting Officer.

6. PERIOD OF PERFORMANCE

Project shall be completed within 360 calendar days after the start-work date specified in the notice to proceed for implementation issued by Government.

7. EQUIPMENT APPROVAL

Upon acceptance of this contract, and prior to ordering of equipment, specifications for the equipment shall be submitted for approval by Government.

8. WARRANTY

Warranty shall be provided an accordance with FAR 52.246-21

9. OPERATION AND MAINTENANCE TRAINING

GHP manufacturer shall provide hands-on training regarding operation and maintenance of the GHP units, consisting of thorough familiarization with factory-developed operating and maintenance procedures on unit components, controls, and periodic maintenance requirements. Government shall designate those individuals to be trained, such training to be accomplished during the period of installation of the GHP units. Six (6) copies of operation and/or maintenance manuals shall be provided, listing step-by-step procedures required for system startup, operation, and shutdown, a brief description of all system components and their basic operating features, model numbers, parts lists, routine maintenance procedures, possible breakdowns and repairs, a trouble shooting guide, piping and equipment layouts, and simplified wiring and control diagrams of the system as installed.

10. SUBCONTRACTOR SELECTION

Contractor may perform some or all of these services using subcontractors. Contractor shall select subcontractors using those normal competitive procedures employed by Contractor; however, in no event shall any contractor which has been excluded from Federal Procurement Programs pursuant to 48 CFR 9.404 perform any services for Contractor under this contract. Contractor may submit the names of proposed subcontractors to the Contracting Officer to ensure than they are not on the GSA's list of excluded contractors.

11. RELATIONSHIP OF PARTIES

Government acknowledges that Contractor and subcontractor personnel shall perform their work as independent contractors and that Government shall have no direct control and supervision of Contractor of subcontractor employees, who shall not be considered employees or agents of Government for any purpose.

12. PAYMENT

The total cost for implementation of the project in 329 housing units is $2,174,361. Gulf Power Company offers a rebate of $140 per unit for each electric domestic water heater which replaces a gas water heater. The total rebate amount of $46,060 shall be used to reduce the cost of the project to the Government, thus the net project cost shall be $2,128,301. Government has $1,408,301 to apply to the project, the remaining $720,000 to be financed by Contractor.

The total monthly energy dollar savings amount available for payback is $8,786. To help ensure positive cash flow in the housing utility budget, only $8,500 shall be committed to pay back to financed amount. The indicator interest rate at this time is 7.06%. Given a principal amount of $720,000, an interest rate of 7.06%, and a monthly payment of $8,500, the financed amount will be repaid in 118 months as detailed in the payment schedule, Supplement 3 to Exhibit C.

The monthly payment of $8,500 shall appear as a line item on the bill for electric service from Gulf Power. Repayment shall commence with the first monthly billing period following acceptance of the project by government. At any time during the pay back period, Gulf Power shall accept additional payments amounts with no prepayment penalty. Any such additional sums shall be used to reduce the outstanding principal balance, maintaining the $8,500 monthly payment, thereby shortening the payback period and reducing the total amount of interest paid. Each time an additional payment is made, the payment schedule shall be recalculated to show the new payback period.

13. DELIVERABLES

Final as-built drawings shall be provided to Government in AutoCAD format.

14. WAGE DECISION

Davis-Bacon General Decision No. FL970019 applies. See Supplement 4.

15. LIFE CYCLE COST ANALYSIS

See Supplement 5.

16. POINTS OF CONTACT

Contracting Officer	Housing Representative	EIC
Mary Charles Parker	Harry Brown	Paul Townsend
NAVFAC Contracts	Housing Officer	NAS Whiting Field
NAS Whiting Field	NAS Pensacola	(850) 623-7181, X47 COM
(850) 623-7592 COM	(850) 452-5111 COM	(850) 623-7747 FAX
(850) 623-7490 FAX	(850) 452-4498 FAX	

17. INCORPORATION OF ADDITIONAL CLAUSES

In addition to the clauses contained in the underlying GSA AreaWide Utilities Contract, the following clauses are incorporated into this contract. Referenced clauses are incorporated with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available.

52.211-10 **Commencement and Prosecution of Work**. The installation contractor shall be required to (a) commence work under this contract within 30 calendar days after the start-work date specified in the notice to proceed, (b) prosecute the work diligently, and (c) complete the entire work ready for use not later than 360 calendar days after receipt of the notice to proceed.

52.211-13 **Time Extensions**

SUPPLEMENT 5 EXHIBIT "C"

WHITPINa.rpt

Life Cycle Cost Analysis — Study: WHITPINE.LC

LCCID FY96 — 09/03/98 09:36:46

Project no. FY & Title: 98 Whiting Pines
Installation & Location: NAS Whiting Field FLORIDA
Design Feature: Geothermal Heat Pumps
Alternative: Base Case
Name of Designer:

Basic Input Data Summary

Criteria Reference: Tri-Service MOA for Econ Anal/LCC (Energy)

Discount Rate: 3.8 %

Key Project-Calendar Information

Date of Study (DOS)	Aug-98
Midpoint of Construction (MPC)	Dec-98
Beneficial Occupancy (BOD)	Mar-99
Analysis End Date (AED)	Mar-19

Cost/Benefit Description	Cost in DOS $	Equivalent Uniform Differential Escalation Rate	Time(s) Cost Incurred
Investment Costs	$0	0.00%	0 0
Electricity	$77,818	-0.63%	Sep99-Sep18
Electric Demand	$0	-0.63%	Sep99-Sep18
Natural Gas	$33,865	0.84%	Sep99-Sep18
HVAC Maint	$15,000	0.00%	Sep99-Sep18
HVAC/DWH Replacement	$265,000	N/A	Jan04-Jan19
DWH Replacement	$50,000	N/A	Jan04-Jan18
Gas Dist System	$144,377	0.00%	Jan00

Other Key Input Data

Location - FLORIDA — Census Region: 3
Rates for Industrial Sector — Tables From: Apr-97

Energy Type	Unit Cost	Consumption	Projected
Electricity	$18.63 /MBtus	4177 MBtus	Mar99-Mar19
Electric Demand	N/A	$0.00E+00K	Mar99-Mar19
Natural Gas	$6.50 /MBtus	5210 MBtus	Mar99-Mar19

WHITPINb.rpt

Life Cycle Cost Analysis

Study: WHITPINE.LC

LCCID FY96

09/03/98 09:37:09

Project no. FY & Title: 98 Whiting Pines
Installation & Location: NAS Whiting Field FLORIDA
Design Feature: Geothermal Heat Pumps
Alternative: Geothermal Heat Pumps
Name of Designer:

Basic Input Data Summary

Criteria Reference: Tri-Service MOA for Econ Anal/LCC (Energy)

Discount Rate: 3.8 %

Key Project-Calendar Information

Date of Study (DOS)	Aug-98
Midpoint of Construction (MPC)	Dec-98
Beneficial Occupancy (BOD)	Mar-99
Analysis End Date (AED)	Mar-19

Cost/Benefit Description	Cost in DOS $	Equivalent Uniform Differential Escalation Rate	Time(s) Cost Incurred
Investment Costs	$646,903	0.00%	Dec98
Electricity	$90,970	-0.63%	Sep99-Sep18
Electric Demand	$0	-0.63%	Sep99-Sep18
Natural Gas	$0	0.84%	Sep99-Sep18
HVAC Maint	$7,500	0.00%	Sep99-Sep18

Other Key Input Data

Location - FLORIDA
Rates for Industrial Sector

Census Region: 3
Tables From: Apr-97

Energy Type	Unit Cost	Consumption	Projected
Electricity	$18.63 /MBtus	4883 MBtus	Mar99-Mar19
Electric Demand	N/A	$0.00E+00K	Mar99-Mar19
Natural Gas	$6.50 /MBtus	0 KBtus	Mar99-Mar19

A-6-8

Life Cycle Cost Analysis   Study: WHITPINE.LC
LCCID FY96   09/03/98 09:37:29
Project no. FY & Title: 98 Whiting Pines
Installation & Location: NAS Whiting Field FLORIDA
Design Feature: Geothermal Heat Pumps
Name of Designer:

Alternative Comparison Summary

Tri-Service MOA for Econ Anal/LCC (Energy)

Discount Rate 3.8 %

Ref#	Alternatives Analyzed Description/Title	LCC (Net PW)	Initial Costs++	Avg. Annual Energy Use
1	Base Case	$2,298,934	$0	9387
2	Geothermal Heat Pumps	$1,922,482	$638,911	4883

Table I. Key Data for Economic Ranking
++ Includes Other Pre-Occupancy Costs, if any

Ref #	Construction/ Acquisition Costs	Energy & Water Costs	Routine M&R/ Custodial Costs	Major Repair & Replacement Costs	Other Costs/ Monetary Benefits	Total
1	$0	$1,518,283	$206,869	$573,782	$0	$2,298,934
2	$638,911	$1,180,135	$103,436	$0	$0	$1,922,482

Table II. Life Cycle Cost Comparison (Actual Net PW Values)*

Ref #	Operating & M&R Costs/ Benefits	Capital Costs/ Benefits	Total
1	$1,725,152	$573,782	$2,298,934
2	$1,283,571	$638,911	$1,922,482

Table III. Life Cycle Cost Comparison (Actual Net PW Values)*

Life Cycle Cost Analysis   Study: WHITPINE.LC
LCCID FY96   09/03/98 09:37:29
Project no. FY & Title: 98 Whiting Pines
Installation & Location: NAS Whiting Field FLORIDA
Design Feature: Geothermal Heat Pumps
Name of Designer:

Alternative Comparison Summary

Tri-Service MOA for Econ Anal/LCC (Energy)

Discount Rate 3.8 %

Ref #	Operating & M&R Costs/ Benefits	Capital Costs/ Benefits	Total	SIR	DPP
1	Baseline Alternative: Lowest Initial Investment Cost				
2	-$441,581	$65,129	-$376,452	6.8	10

Table III.A Incremental Life Cycle Costs* (Relative to Baseline)

*Net PW Equivalents on Aug 98; in Thousand Dollars; in Constant Aug 98 Dolla
*Energy Escalation Rates from NIST Handbook 135 Supplement dated Apr 97

A-6-10

Fort Polk

US Army Saves $44 Million in Residential GHP Retrofit

Main Story / Project Information / Shared Energy Savings / GHP Benefits / Credits

AT FORT POLK, Louisiana, the installation of over 4,000 GHPs has enabled US Army energy managers to reduce energy and maintenance costs while avoiding cuts in service or salaries on the base. About half of the base's energy bill was for housing energy consumption. With the new GHP system, savings in utility and maintenance bills are expected in the range of $3.3 million annually, or a net present value of $44 million over the 20-year life of the project.

Financed by a private company, the energy and maintenance-saving project bears no up-front costs to the government. The $18-million contract was signed in February 1994, and the project was completed in August 1996.

The entire housing stock, consisting of 4,003 units ranging in size from 1,073 to 2,746 square feet in 1,296 buildings, was retrofitted with GHPs. About 80% of the units had air-source heat pumps and electric water heaters. The remainder had central A/C and were heated by natural gas forced-air furnaces.

Some 23,000 military personnel and their families live in the base housing on the 300 square mile facility. In this part of the country, cooling is the main requirement. Since the new system was installed, service calls on hot summer days have dropped from 90 per day to almost zero.

The GHP system is expected to account for 23.3 million kWh of the conservation project's annual energy savings of over 33.6 million kWh (equal to 57,593 barrels of fuel oil per year), and virtually all of the 19,800 MMBtu of gas savings. The balance of the savings is derived from added insulation, lighting improvements, installation of low-flow hot water outlets, and hot water generation with the use of desuperheaters in the GHP system. In summer, hot water is free.

Cleaner air locally is another benefit of the system. Annual pollutant emissions reductions are estimated at approximately 38,480 tons of carbon dioxide (CO_2), 100 tons of sulfur dioxide (SO_2), and 90 tons of nitrogen oxide (Nox).

Project Information

Name and Location:

- Fort Polk
- Louisiana

Completion Date:

- August 1996

Housing Type:

- 4,003 living units ranging in size from 1,073 to 2,059 square feet

System:

- Approximately 6,600-ton closed loop GHP system
- 4,003 ClimateMaster VZ series GHPs, ranging from 1.52.5 tons
- Over 8,000 boreholes and almost six million feet of 1" polyethylene pipe
- Borehole depths of 130325 feet

DOD Project Engineer:

- Greg Prudhomme, Environmental Engineering

DOD Program Manager:

- Bob Starling, US Army Corps of Engineers

Project Engineer:

- Richard Gordon
- Applied Energy Management Techniques

Energy Services Contractor:

- Bob Howell, Project Manager
- Co-Energy Group

Equipment Manufacturer:

- Brian Haggert, ClimateMaster

Shared Energy Savings

The Fort Polk project is financed and managed by Co-Energy Group, an energy services firm, under a contract awarded by the Huntsville Engineering and Support Center of the Army Corps of Engineers, and administered by Fort Polk.

The GHP installation is expected to yield annual electric, natural gas, and maintenance savings totaling about $3.3 million. Annual savings on the utility bill for the base are expected to be almost $2 million. Because the equipment will be serviced and maintained by the energy services company (ESCO) for the life of the contract, the entire baseline maintenance costs, estimated by the army at about $1.3 million annually, will be saved.

Under the shared energy savings (SES) contract, Fort Polk will keep 22.5%, or $742,500 of the expected annual energy and maintenance savings for 20 years. The Department of Defense (DOD) will return 77.5% of the savings to ESCO. At the end of the 20-year contract period, Fort Polk will own the equipment.

The contract will enable the army to shift maintenance to a vendor and to cap its future expenditures for family housing HVAC maintenance at about 18 cents per square foot per year and $262 per housing unit per year. This amount is about 72% of the army's estimated baseline maintenance costs.

In comparison, data from a 1994 survey by the Building Owners and Managers Association show an average HVAC maintenance cost of 29 cents per sq ft per year for federal, state, and local government buildings.

Fort Polk managers acknowledge that without the shared savings contract, the procurement process for the large-scale GHP system would have been extremely

difficult. The joint DOD/DOE Strategic Environmental Research and Development Program (SERDP) is collecting energy and maintenance data from the Fort Polk GHP installation to lay the groundwork for similar projects at other bases.

GHPs are now being installed at facilities operated by all three branches of the armed services.

GHP Benefits

- **Lower Utility Costs:** The GHP system is projected to save about 50% of the former heating, cooling, and water heating bills, totaling 32 million kWh annually.
- **Capital Costs:** $0 for Fort Polk. Co-Energy, a private company, provided the capital in return for 77.5% of the energy and maintenance savings.
- **Peak Electrical Demand Reduction:** Peak demand has been reduced by four megawatts annually.
- **Improved Comfort:** Residents are very happy with the new system. Service calls have dropped from 90 per day to nearly zero on hot summer days.
- **Environmentally Safe:** Meeting new government energy standards, the GHP refrigerant circuits are precisely sealed at the factory and will seldom require recharging.
- **Vandalism:** All equipment is indoors, minimizing the risk of vandalism, theft, or corrosion from weather.

"The beauty of it all is that the onus to save Btus is on the contractor. I'm a happy camper knowing that I have a single entity that I am going to deal with over the next twenty years, an entity with a profit motivation for saving energy and maintenance dollars."

-Jim Kelley, Manager of Engineering and Planning,

Directorate of Public Works, Fort Polk

International Ground Source Heat Pump Association
Oklahoma State University
490 Cordell South
Stillwater, OK 74078-8018
Phone (405) 744-5175
Fax (405) 744-5283
1-800-626-4747

Department of Energy
Geothermal Division
1000 Independence Ave. S.W.
Washington, D.C. 20585
(202) 586-1512

Geothermal Heat Pump Consortium Inc.
701 Pennsylvania Ave. NW, 5th Floor
Washington, D.C. 20004-2696
(202) 508-5512

Main Story / Project Information / Shared Energy Savings / GHP Benefits / Credits

Return to Case Study Index

Case Study

GeoExchange Saving Millions at Folk Polk, Louisiana

U.S. Department of Energy
SERDP

Project

Background

In early 1994, the U.S. Army signed the Department of Defense's (DOD's) largest energy savings performance contract (ESPC) to date to convert the heating and cooling systems of 4,003 military family housing units at the Fort Polk Joint Readiness Training Center, in Louisiana, to GeoExchange. Other energy efficiency measures also were implemented as part of the ESPC including compact fluorescent lighting, low-flow shower heads, and attic insulation. A private energy services company (ESCO) financed the project with no up-front costs to the government. The $18 million project was completed in August 1996 and is expected to reduce energy and maintenance costs by about $3.3 million per year -- a present value of $44 million over the 20-year life of the ESPC. Under the terms of the ESPC, DOD returns 77.5% of the total savings to the ESCO for their debt service and profit. The government keeps the remaining 22.5%, which equates to almost $745,000 annually or a 20-year present value of almost $10 million.

The Base

The Fort Polk Joint Readiness Training Center in Leesville, Louisiana, trains military and civilian personnel in airlift, close-air support, resupply, and battlefield combat missions. The 300-square-mile facility contains military offices, training centers, equipment and storage warehouses, and a hospital. Altogether some 23,000 military personnel and family members live in base housing. Family housing is located in two areas called the North Fort and the South Fort. The housing stock consists of 4,003 units in 1,296 buildings constructed in nine phases between 1972 and 1988. The housing units are mostly apartments, two-story townhouses, and duplexes, and range in size from 900 to 1,400 square feet.

Project Description

GeoExchange units manufactured by ClimateMaster of Oklahoma City replaced 3,243 air-source heat pumps and 760 central air conditioners and natural gas forced-air furnaces. Each housing unit is now served by a 1½- or 2-ton unit for a total of 6,593 tons, or an average of 1.65 tons per housing unit. The seasonally-adjusted energy efficiency ratio (SEER) of the existing equipment was estimated to be about 7 to 8. The new ClimateMaster GeoExchange units installed in each residence have SEER ratings of about 15.5.

Each GeoExchange unit is served by its own closed-loop ground heat exchanger consisting of two boreholes, each with a vertical U-bend loop of polyethylene pipe connected in parallel. The boreholes are 4 inches in diameter and range from 125 to 450 feet deep. According a report from the Oak Ridge National Laboratory, a total of 1,810,628 feet of vertical bore was drilled, not including the upper 3 feet of each bore that is not part of the heat exchanger. A U-bend loop is installed in each bore, making a total of 3,621,256 feet of 1-inch, SDR-11 high-density polyethylene pipe -- about 686 miles. The bores were backfilled with standard bentonite based grout, the Oak Ridge report states.

The geology of Louisiana is conducive to GeoExchange, according to Barry Peterson, geothermal sales representative. "There isn't much rock you have to go through," Peterson said. The high water table increases heat transfer to and from the surrounding earth. Use of vertical bore holes rather than horizontal trenching meant less landscape had to be disturbed.

Sizable Challenge

Renovation of Fort Polk turned out to be a remarkable story in more ways than one. A trailblazing spirit took over what could have been a fairly straightforward HVAC replacement. The project was spearheaded by the ESCO, Co-Energy Group, of Santa Monica, California, which normally has about 12 core employees. On this project, Co-Energy took on more of the tasks as the subcontractors bailed out or failed to meet requirements. As a result, the ESCO swelled to some 150 temporary employees struggling to renovate Fort Polk's military housing in time to meet the August 30, 1996, deadline. In terms of sheer size, the project is said to be the single largest known installation site ever for geothermal heat pumps.

Nine different drilling contractors were working in the soft, damp Louisiana clay that clung persistently to the drill bits and sought to instantly fill in freshly bored holes. At one point, as many as 27 separate drilling rigs were operating at once on the base, drilling 75 to 80 holes per day. As many as 20 heats pumps were installed per day.

Phillips Driscopipe, Inc., supplied "Uni-Coils" of polyethylene tubing made for GeoExchange systems

at two factories in California and Oklahoma. At one point, demand for this project alone kept one line of one of the plants busy for almost an entire year, according to Mr. Peterson. Uni-coils (pre-assembled U-bend loops sized for the bore depth) can be installed quickly.

Brian Haggert, a division vice president for the Environmental Group of LSB, which owns ClimateMaster, said a project of this scope would have been impossible without the remarkable project management and coordination efforts made by Co-Energy.

New Product

To make things go as smoothly as possible, the GeoExchange units were supplied complete and ready to go. This took a major effort by ClimateMaster, which tailored its heat pumps specifically for this project. "The product they needed didn't exist," said LSB's Brian Haggert. Thomas Mitchell, President of Co-Energy, said some initial experimental geothermal units were not selected because they had separate pump, fittings, and power hookups. There was no room in these housing units for a remote pump. Often only a closet space was available. The ClimateMaster units installed at Fort Polk are completely self-contained, which saved space and shortened installation time.

Energy Savings

The Oak Ridge National Laboratory is carrying out an evaluation of the project. Statistically valid data has been collected on the feeders serving the housing area, and on a sample of apartments for about one year before, during, and after the retrofits. Results through January 1997 indicate that the project has resulted in a 25.6 million kWh savings in electrical energy use, or 32.0% of the pre-retrofit electrical consumption in family housing, for a typical meteorological year. Natural gas savings are estimated at 260,000 therms per year.

Electrical energy savings varied by feeder according to several factors. As expected, electrical savings were lower on feeders serving housing which previously had natural gas space and water heating. Nevertheless, in addition to saving 100% of their natural gas use, the housing on these feeders saved an average of 14% in total annual electrical use. For housing which had been previously served by air-source heat pumps and electric water heaters, the average electrical savings was about 35%.

Table 1 (at right) summarizes the energy savings by feeder for a typical meteorological year. Figure 1 presents daily electrical energy use plotted against daily average temperature in the pre- and post-retrofit periods for a typical all-electric feeder, feeder 1.

Figure 2 presents the 15-minute electrical demand for a peak cooling day, pre- and post-retrofit, for feeder 2, which is typical of all-electric feeders. Again, peak demand savings varied by feeder according to whether the housing was originally gas/electric or all-electric. Housing that was originally gas/electric achieved a reduction in peak electrical demand of 53.5%, while all-electric housing saw a reduction of 35.5%. The difference is explained by the fact that the central air conditioners in the gas/electric areas were installed in 1972 and 1975, whereas most of the air-source heat pumps were installed in the 1980s, some as recently as 1988. Overall, the project reduced peak electrical demand in family housing by 6,679 kW, which is 39.7% of the pre-retrofit summer peak demand.

Maintenance

Under the energy savings performance contract, the Army pays the ESCO a fixed percentage of its

pre-contract-award maintenance costs, enabling the Army effectively to cap its future expenditures for family housing HVAC maintenance at about $0.18 per square foot per year, or $262 per housing unit per year. This is about 78% of the Army's estimated "20-year average" baseline maintenance costs of about $336 per housing unit per year (about $0.24 per square foot) based on bids received for a never-awarded maintenance contract.

Energy Savings Performance Contracting

Fort Polk managers acknowledge that without the shared savings arrangement of the ESPC, the procurement for the large-scale GeoExchange system would have been extremely difficult. Federal agencies can now undertake energy efficiency projects through new, non-traditional procurement options such as so-called the regional Super ESPCs intended to reduce the time it takes to award a delivery order to six months and attract industry participation. GeoExchange may soon be included in pilot Super ESPCs that involve technology-specific contracts.

Award Winning Project

So successful was the GeoExchange/ESPC project at Fort Polk that it was recognized with Vice President Gore's Hammer Award on July 15, 1997. The Hammer Award is bestowed on innovative teams that make government "work better and cost less," and symbolizes efforts to "hammer away" at unnecessary bureaucracy and costly inefficiency. The award was presented to each of the project team members including Fort Polk, Louisiana State University, the U.S. Army Corps of Engineers Cold Regions, the U.S. Army Engineering and Support Center in Huntsville, and the Co-Energy Group.

Sources

U.S. Army to Save Millions in Largest Shared Savings Residential GHP Project at Fort Polk, Louisiana, Strategic Environmental Research and Development Program (SERDP) case study, Technology Prospects, Inc., May 1, 1996.

Quarterly Report, Jan-Mar 1997, Oak Ridge National Laboratory, Patrick J. Hughes and John A. Shonder.

Army Base Undergoes Massive HVAC Retrofit, Air Conditioning, Heating & Refrigeration News, Ed Bas, July 15, 1996.

Retrofits Cut Electricity Use by 32 MMkWh/Yr, Energy User News, Mike Randazzo, November 1994.

Case Study: Ft. Polk -- GeoExchange Project saves U.S. Army $44 million at Ft. Polk, PEPCO Services, Inc.

Ft. Polk Receives Vice President Gore's Hammer Award for GeoExchange Installation, Press Release, Geothermal Heat Pump Consortium, July, 18, 1997.

U.S. Department of Energy

SERDP

Table 1

Table 1 -- Energy Savings by Feeder forTypical Meteorological Year				
Feeder	Pre-Retrofit Annual kWh	Post-Retrofit Annual kWh	Total Savings	Percent Savings
1	2,873,818	2,008,532	865,286	30.1%
2	27,722,779	19,047,205	8,675,575	31.3%
3	1,273,006	971,875	301,131	23.7%
4	170,119	176,779	(6,660)	-3.9%
5	2,134,857	2,125,661	9,196	0.4%
6	1,551,444	999,222	552,221	35.6%
7	13,921,102	6,169,796	7,751,306	55.7%
11	2,284,612	1,910,931	373,681	16.4%
12	2,008,792	1,670,374	338,418	16.8%
13	2,214,590	1,848,926	365,664	16.5%
14	2,530,362	2,085,527	444,835	17.6%
15	4,132,427	2,669,872	1,462,555	35.4%
16	6,111,433	4,755,023	1,356,410	22.2%
17	4,015,635	3,032,894	982,741	24.5%
18	3,393,136	2,354,659	1,038,477	30.6%
19	3,693,865	2,570,669	1,123,197	30.4%
Total	80,031,977	54,397,946	25,634,031	32.0%

U.S. Department of Energy

SERDP

Contact Information

DOD Project Engineer

Greg Prudhomme, Environmental Engineering, Fort Polk, LA (318) 531-6029

DOD Program Manager

Bob Starling, U.S. Army Corps of Engineers, Huntsville, AL (205) 895-1531

Project Engineer

Richard Gordon, Applied Energy Management Techniques, Corvallis, OR (503) 757-7514

Energy Services Company

Tom Mitchell, President, Co-Energy Group, Santa Monica, CA (310) 395-6767
Bob Howell, Project Manager, Co-Energy Group, (310) 395-6767

GeoExchange Manufacturer

Brian Haggert, ClimateMaster, Oklahoma City, OK (405) 745-6000

Technical Advisors

Gary Phetteplace, U.S. Army Cold Regions Research & Engineering Laboratory, Hanover, NH (603) 646-4248
Patrick J. Hughes, Oak Ridge National Laboratory, Oak Ridge, TN (423) 574-9337

SERDP GeoExchange Project Manager

Dr. William N. Sullivan, Sandia National Laboratories, Albuquerque, NM (505) 844-3354

Case Study

Fort Irwin, California

U.S. Department of Energy

SERDP

Index

Background

Army Showcase Facility Uses GHPs and Cuts Energy Costs in Half

At the National Training Center in California!s Mojave Desert, where temperatures reach 130 degrees Fahrenheit in the summer months, 220 family housing units were constructed in 1995 with 600 tons of geothermal heat pumps. The geothermal heating and cooling system uses the base water system as a heat source or sink via a single closed water loop. The $1.3 million GHP project is expected to save Fort Irwin as much as 50 percent of HVAC electricity costs. An investment of $610,000 by the local utility, Southern California Edison (SCE), enabled the Sacramento District of the Army Corps of Engineers to gain approval for the project. Because of the potential savings of 2.2 million kWh per year for the 220 units and the opportunity to gain

first-hand cost and performance data on GHPs, SCE agreed to contribute the capital costs, as well as all design and specifications for the GHP system, with the agreement that the utility would manage the facility's energy needs after a year. The success of the project has led to another GHP installation at Fort Irwin.

U.S. Department of Energy

SERDP

Project

Fort Irwin, like other military installations, faces federal mandates to reduce overall base energyconsumption. The new housing construction scheduled for the base provided an opportunity to investigate and demonstrate energy efficiency improvements offered by alternatives to conventional heating and cooling systems. Modeled comparisons between the conventional systems currently used for base housing -- propane heating and split-system air-conditioning and five other heat pump options, including GHPs, showed that all heat pump alternatives were favored over the existing conventional systems.

Fort Irwin management was particularly interested in the geothermal heat pump. A GHP was installed at a representative 1,525-square-foot unoccupied residence, while another unoccupied house of a similar design was chosen as a point of reference for a control baseline. The annual projections based on the test-residence data indicated that the GHP would reduce annual site energy input as required by the conventional systems by about 50,800 Btu per square foot per year, a reduction of approximately 72 percent, corresponding to a projected energy cost reduction of about 49 percent. In the new residential construction, individual GHPs in each residence are tied together by an underground distribution loop from which heat can be extracted for heating or to which heat can be rejected for cooling. The distribution loop rejects excess heat to, or extracts required heat from, reservoir water available on the base. This is accomplished at a central heat exchanger and pumping station. The Fort Irwin project has been awarded the Showcase Facility Award for fiscal year 1996 by the Department of the Army.

Gary Headley, the Project Manager for the U.S. Army Corps of Engineers, attests to the success of the GHP technology in the Fort Irwin residential application, saying that he is pleased enough with the results that he would like to do more GHP projects. And Rene Quinones, Chief Master Planner and Energy Manager for Fort Irwin, states that the project "surpassed all expectations" in terms of both energy savings and comfort. For further information about geothermal heat pumps, SERDP, or other GHP projects within DOD, please contact Dr. Chang Sohn, at the U.S. Army Construction Engineering Research Laboratory (CERL) 1-800-USA-CERL.

Facility

- 220 new 2&3 bedroom garden style apartments
- Water reservoir for domestic water (75'-801)
- Number of heat pumps: 220
- Size of heat pumps: 3 - 3.5 tons
- Heat pump manufacturer: WaterFurnace
- Reservoir heat exchanger-: double plate
- Common loop to all houses: 14,000 feet
- Flow rate: 350 gpm

Location

Fort Irwin is located in Southern California, within the Mojave Desert.

Contact Information

DOD Project Manager: Gary Headley, U.S. Ai-my Corps of Engineers, Sacramento District, Sacramento,
CA (916) 557-7445

DOD Program Manager: Eric Loughner, U.S. Army Corps of Engineers, Washington, D.C., (202) 761-1146

Army Housing Officer: Alexander Houtzager, ASCIM-Housing, Ft. Belvoir, VA (703) 355-7513

Utility: Irving Katter, Southern California Edison, Los Angeles, CA, (818) 302-1212

Project Manager: Clyde Trego, Actus-Sundt, Inc., Napa, CA, (707) 252-7511

Ground Loop Installer: Sam Shek-hter, Atlas Mechanical, Inc., San Diego, CA (619) 554-0700

Fort Irwin Energy Manager: Rene J. Quinones, Directorate of Public Works, (619) 380-5048

U.S. Department of Energy

SERDP

Naval Activity Energy Consumption for Apr 97 - Mar 98 (2nd Qtr FY98)*

Includes Housing and Shore for Navy and Marine Corps Activities; excludes Government Owned/Contractor Operated (GOCO), Cold Iron, Transmitter, Simulator and Miscellaneous Support

Energy Type	MBtu Consumed		Change From FY85 (%)	By Energy Type (%)
	Apr 97 - Mar 98	FY85**		
Electricity	29,027,883	29,076,897	-0.17	43.05
Fuel Oils	11,308,755	26,993,823	-58.11	16.77
Natural Gas	22,682,653	25,531,380	-11.16	33.64
Propane Gas	251,741	314,986	-20.08	0.37
Coal	2,084,016	4,106,710	-49.25	3.09
Steam & Hot Water	999,337	1,288,378	-22.43	1.48
Residual	882,251	1,240,804	-28.90	1.31
Distillate	136,338	63,408	115.02	0.20
Reclaimed Oil	49,954	244,430	-79.56	0.07
Total (12 Months)	67,422,928	88,860,816	-24.13%	100.00%
Navy and Marine Corps (ksf)	610,373	629,381	-0.00%	
Navy and Marine Corps (MBtu/ksf)	110.46	141.19	-21.50%	
Navy Shore and Housing (MBtu/ksf)	117.38	149.71	-22.38%	

* The interim energy reduction goal for the end of March 98 is -18.75% below FY85 consumption. The percentage is derived by straight line interpolation of the 30% decrease per gross square foot from FY85 to FY2005.

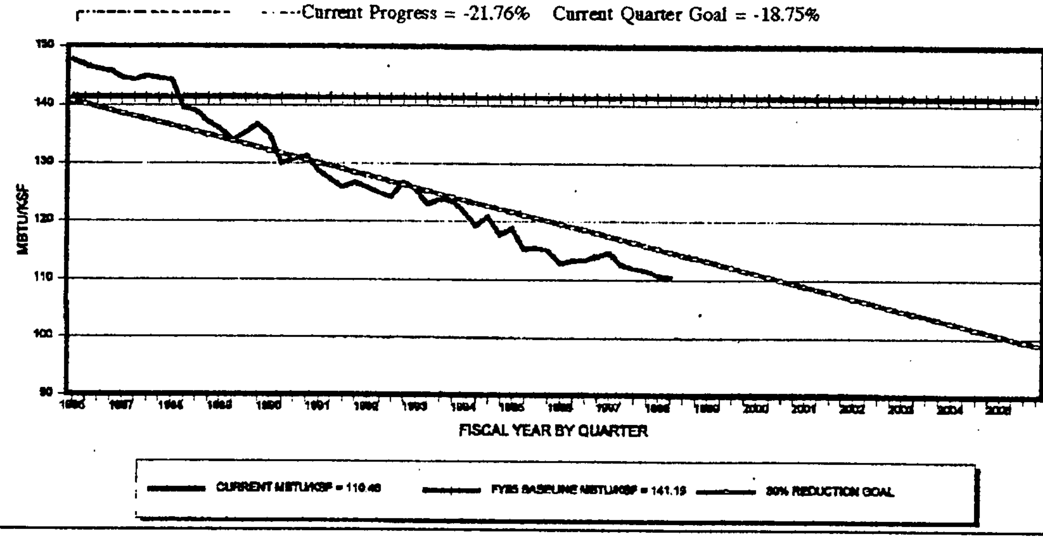
** These FY85 figures incorporate all corrections approved to date.

ENERGY REDUCTION PROGRESS

2005 GOAL=30% REDUCTION

2ND QUARTER FY 98 (APR 97 - MAR 98)

Current Progress = -21.76% Current Quarter Goal = -18.75%



C-1

Energy Unit Conversion Table

Btu	TO ergs	Multiply Btu	by	1.06E+10
Btu	TO foot-lbs	Multiply Btu	by	778.3
Btu	TO gram-calories	Multiply Btu	by	252
Btu	TO horsepower-hrs	Multiply Btu	by	0.0003931
Btu	TO joules	Multiply Btu	by	1054.8
Btu	TO kilogram-calories	Multiply Btu	by	0.252
Btu	TO kilogram-meters	Multiply Btu	by	107.5
Btu	TO kilowatt-hrs	Multiply Btu	by	0.0002928
Btu/hr	TO foot-pounds/sec	Multiply Btu/hr	by	0.2162
Btu/hr	TO gram-cal/sec	Multiply Btu/hr	by	0.07
Btu/hr	TO horsepower-hrs	Multiply Btu/hr	by	0.0003929
Btu/hr	TO watts	Multiply Btu/hr	by	0.2931
Btu/min	TO foot-lbs/sec	Multiply Btu/min	by	12.96
Btu/min	TO horsepower	Multiply Btu/min	by	0.02356
Btu/min	TO kilowatts	Multiply Btu/min	by	0.01757
Btu/min	TO watts	Multiply Btu/min	by	17.57
Btu/sq. ft/min	TO watts/sq. in	Multiply Btu/sq. ft/min	by	0.1221
kilowatts	TO Btu/min	Multiply kilowatts	by	56.92
kilowatts	TO foot-lbs/min	Multiply kilowatts	by	4.43E+04
kilowatts	TO foot-lbs/sec	Multiply kilowatts	by	737.6
kilowatts	TO horsepower	Multiply kilowatts	by	1.341
kilowatts	TO kg-calories/min	Multiply kilowatts	by	14.34
kilowatts	TO watts	Multiply kilowatts	by	1000
kilowatt-hrs	TO Btu	Multiply kilowatt-hrs	by	3413
kilowatt-hrs	TO ergs	Multiply kilowatt-hrs	by	3.60E+13
kilowatt-hrs	TO foot-lbs	Multiply kilowatt-hrs	by	2.66E+06
kilowatt-hrs	TO gram-calories	Multiply kilowatt-hrs	by	859850
kilowatt-hrs	TO horsepower-hrs	Multiply kilowatt-hrs	by	1.341
kilowatt-hrs	TO joules	Multiply kilowatt-hrs	by	3.60E+06
kilowatt-hrs	TO kg-calories	Multiply kilowatt-hrs	by	860.5
kilowatt-hrs	TO kg-meters	Multiply kilowatt-hrs	by	3.67E+05
kilowatt-hrs	TO lbs of water evap. at 212øF	Multiply kilowatt-hrs	by	3.53
kilowatt-hrs	TO lbs of water ^ from 62ø-212øF	Multiply kilowatt-hrs	by	22.75